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Proceedings of the 2006 Australian Systematic Botany Society (ASBS) conference

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The first four papers in this issue of *Telopea* are a sample of those presented at the 2006 Australian Systematic Botany Society (ASBS) conference. This conference, held 13–15 November 2006 at James Cook University (Cairns) was the first ASBS meeting in the tropics for more than a decade. Over 60 local and international delegates heard 40 presentations on a wide range of topics in plant systematics and evolution. This is the first time *Telopea* has published papers from an ASBS meeting as a group. It is our hope that it is the beginning of a tradition.

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Four of the papers in this issue of *Telopea* were presented at the 2007 Australian Systematic Botany Society (ASBS) conference, held 24–28 September in Palmerston, Northern Territory. Nearly 60 Australian and international delegates heard over 30 presentations on a wide spectrum of botanical subjects including systematics, ecology, conservation, and ethnobotany. This is the second consecutive ASBS conference of which the proceedings have been published in *Telopea* and establishes, we sincerely hope, an enduring and mutually rewarding relationship. One further paper from this meeting will be published in *Cunninghamia.*

The financial assistance of the Australian Biological Resources Study (ABRS) in bringing these papers to publication is gratefully acknowledged. The conference Organising Committee are also thanked for putting together an interesting and well-managed meeting.

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Large indels obscure phylogeny in analysis of chloroplast DNA (*trn*L-F) sequence data: Pomaderreae (Rhamnaceae) revisited

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Abstract

Phylogenetic analysis of 69 ingroup-taxa of Pomaderreae using *trn*L-F sequences confirm the monophyly of the tribe. The analysis was impeded by a paucity of informative characters and the presence of apparently homoplasious indel characters and base changes within the P8 region of the *trn*L intron: the strict consensus tree of the *trn*L-F analysis is less resolved and had fewer supported clades than in a previous ITS analysis (Kellermann et al. 2005). The backbone of the cladogram is not supported and relationships between genera/clades are somewhat uncertain. The genera *Cryptandra*, *Stenanthemum* and *Polianthion* are well supported. *Pomaderris* groups with *Siegfriedia* and *Trymalium*, but only individual clades within these genera receive support. *Blackallia biloba* is related to two atypical species of *Stenanthemum* and *B. connata* to *Cryptandra*, but this grouping depends on the exclusion of homoplasious indel characters. Species of *Spyridium* only group in one clade when these indels are excluded, otherwise they are located in a polytomy at the base of the cladogram. The results mostly agree with earlier findings using ITS sequence data. Two new genera containing atypical species of *Stenanthemum* are suggested. A synopsis of the Australian genera of Rhamnaceae is provided.

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Introduction

Australia has a very rich Rhamnaceae flora with about one quarter of the world's species (c. 250 out of 950) occurring in the country. The majority of species (over 90%) belong to the tribe Pomaderreae, which is almost endemic to Australia. The remaining 10% of species are mostly from genera that are also widespread in the Malesian or Pacific region, and some species occur in southern Australia. A synopsis of the Australian genera of Rhamnaceae is presented in Table 1.

Species of Pomaderreae are found mainly in the temperate to semi-arid southern regions of Australia, but some occur in the tropical north, and arid centre of the continent, and eight taxa are found in New Zealand. There are about 230 species, which are currently classified in eight genera (Table 1). The complex taxonomic history of the major genera in the tribe is reviewed in Kellermann et al. (2005) and Kellermann (2007).

The tribe has been the focus of recent and on-going research in the Australian Rhamnaceae. Walsh revised *Pomaderris* and published an infrageneric classification of the genus (e.g., Walsh 1988, 1990; Walsh & Coates 1997). Rye (1995, 2001) re-instated the genus *Stenanthemum* and revised species from Western Australia (e.g., Rye 1996b).

Table 1. Currently accepted genera of Australian Rhamnaceae.
Tribal classification follows Medan & Schirarend (2004) and Richardson et al. (2000b). Six genera of Rhamnaceae are not assigned to a tribe; five of these occur in Australia.

Tribe	**Genus**	**Species in Australia**
PALIUREAE Reissek ex Endl.	*Hovenia* Thunb.	1 (introduced)
	Ziziphus Mill.	4
COLLETIEAE Reissek ex Endl.	*Discaria* Hook.	2
PHYLICEAE Reissek ex Endl.	*Noltea* Rchb.	1 (introduced)
GOUANIEAE Reissek ex Endl.	*Gouania* Jacq.	2
POMADERREAE Reissek ex Endl.	*Blackallia* C.A.Gardner	2
	Cryptandra Sm.	c. 55
	Polianthion K.R.Thiele	4
	Pomaderris Labill.	c. 70
	Siegfriedia C.A.Gardner	1
	Spyridium Fenzl	40–45
	Stenanthemum Reissek	c. 30
	Trymalium Fenzl	13
RHAMNEAE Hook.f.	*Dallachya* F.Muell.	1
	Rhamnus L.	2 (1 native, 1 introduced)
	Sageretia Brongn.	1
VENTILAGINEAE Hook.f.	*Ventilago* Gaertn.	3
Genera *incertae sedis*	*Alphitonia* Reissek ex Endl.	5
	Colubrina Rich. ex Brongn.	1
	Emmenosperma F.Muell.	2
	Granitites Rye	1
	Schistocarpaea F.Muell.	1

An atypical species of *Pomaderris* was excluded from the tribe and segregated into its own genus, *Granitites* (Rye 1996a). Thiele & West (2004) and Thiele (2007) elucidated the delimitations of the genera *Cryptandra*, *Spyridium* and *Stenanthemum*. Bean (2004) published new species of *Cryptandra* and *Stenanthemum* for Queensland. Kellermann (2006b, 2007) clarified the position of several *Spyridium* taxa that were misplaced in other genera. The revision of the south-eastern species of *Cryptandra* has resulted so far in three publications (Kellermann 2006a, 2006c; Kellermann & Udovicic 2007). Kellermann et al. (2005) published a molecular phylogeny using ITS sequence data, as a result of which a new genus, *Polianthion* K.R.Thiele, was established (Kellermann et al. 2006).

The ITS phylogeny confirmed the monophyly of Pomaderreae, corroborating earlier results by Richardson et al. (2000a) and Fay et al. (2001). The clades found in the strict consensus tree were mostly consistent with the currently accepted genera in the tribe. Some species were clearly misplaced, but re-examination of the morphology of these species confirmed their placement in the molecular phylogeny. The major genera/clades, except *Stenanthemum* and *Blackallia*, received moderate to strong bootstrap and jackknife support. *Stenanthemum* was split into two well-supported clades with the atypical *St. gracilipes* inserted in between the two clades. *Blackallia biloba* and *St. grandiflorum* were sister taxa, and not allied to any of the remaining genera; *B. connata* was placed in *Cryptandra*.

This study was initiated to clarify questions that could not be resolved in the analysis of ITS data (Kellermann et al. 2005) and to augment the molecular data-set available for Pomaderreae with sequences from the *trn*L-F region of cpDNA. In this paper, the resulting phylogenies of the *trn*L-F analysis are presented and we report on the presence of unforeseen problems relating to the structure of the *trn*L-F region, which hampered and complicated the cladistic analysis of the data. The results add to the base of knowledge needed for the completion of the *Flora of Australia* treatment of Rhamnaceae (K.R. Thiele, F. Udovicic, N.G. Walsh & J. Kellermann, in prep.).

Materials & Methods

Sixty-nine ingroup taxa were sequenced from all genera of Pomaderreae. The outgroup consisted of five species from related tribes of Rhamnaceae. Voucher and collection details are listed in Appendix 1. Manuscript names of taxa are used as they are listed in FloraBase (http://florabase.calm.wa.gov.au) at the time of writing (Mar. 2007). In this paper, the abbreviations used for the genera *Pomaderris*, *Polianthion*, *Siegfriedia*, *Spyridium* and *Stenanthemum* are '*P.*', '*Pol.*', '*Si.*', '*Sp.*' and '*St.*'.

Choice of DNA region

The *trn*L-F region consists of the complete *trn*L intron, *trn*L 3' exon, and the intergenic spacer (IGS) between the *trn*L and the *trn*F genes of the chloroplast genome. These genes encode the chloroplast's transfer RNA for Leucine and Phenylalanine, respectively. Both the *trn*L intron and the *trn*L-F IGS are non-coding regions. The *trn*L intron is the only group I intron in the chloroplast genome and has a conserved secondary structure (Simon et al. 2004).

The *trn*L-F region was first used in phylogenetic analyses of *Gentiana* L. (Gielly & Taberlet 1994) and Crassulaceae (Ham et al. 1994). Currently, it is applied in studies at all taxonomic levels. Borsch et al. (2003) used the *trn*T-*trn*F region, which includes the *trn*L-F region, to infer a phylogeny of basal angiosperms. Most frequently, however, *trn*L-F is used for infrafamilial studies, e.g., in Araliaceae (Plunkett et al. 2004), Gentianaceae (Yuan et al. 2003), *Oxylobium* Andrews and related genera (Crisp & Cook 2003), or *Acacia* Mill. (Murphy et al. 2000).

The region has already been employed to examine the relationships of Rhamnaceae with other families (Sytsma et al. 2002; Thulin et al. 1998), to resolve the tribal limits of the family (Fay et al. 2001; Richardson et al. 2000a, b), and in studies on the genera *Ceanothus* Mill. (Islam & Simmons 2006), *Phylica* L. (Richardson et al. 2001) and *Rhamnus* L. s. lat. (Bolmgren & Oxelman 2004).

DNA isolation and sequencing

Genomic DNA was isolated using the method described in Kellermann et al. (2005). A few samples of the *trn*L-F region had to be purified using the QIAquick Gel Extraction Kit (QIAGEN). The *trn*L-F region was amplified using the primers designed by Taberlet et al. (1991). For most species the whole region was amplified with primers C and F with one hold at 95°C for 15 min preceding 30 cycles of 94°C for 30 s, 58°C for 30 s, 72°C for 30 s, and followed by one hold at 72°C for 5 min. In other species, the *trn*L intron and the *trn*L-F IGS had to be amplified separately using primer pairs C/D and E/F, respectively. While the *trn*L-F IGS amplified readily, the annealing temperature frequently had to be lowered to 55°C or 52°C when amplifying the *trn*L intron. Some species with a low yield of genomic DNA, in particular from herbarium specimens, had to be amplified with a semi-nested PCR protocol (Udovicic & Murphy 2002) using products from a previous amplification with primers C and F as template for a second round of PCR. In this second round the *trn*L intron and the *trn*L-F IGS were amplified using the primer pairs C/D and E/F, respectively, and a lower annealing temperature of 55°C. Amplification with primers C and F in the second round of PCR was unsuccessful, a fact already noted by Richardson et al. (2001) for other species of Rhamnaceae.

Phylogenetic analysis

Sequences were aligned as outlined in Kellermann et al. (2005) and analysed using the computer program PAUP*, version 4.0b10 (Swofford 2002). Individual base positions were coded as unordered multistates and gaps were treated as missing data. Insertion/deletion (indel) characters were coded as single binary characters. Uninformative characters were excluded from the data matrix.

A two step search was employed, since the computer ran out of memory when using a more straightforward search strategy (e.g., Kellermann et al. 2005). In the first round, a heuristic search was performed with 1000 replicates using random stepwise addition of taxa and TBR branch swapping. Only five trees were held in each replicate. All shortest trees collected in the 1000 replicates were then used as starting trees for a second round of heuristic search. All trees were swapped to completion, or until a maximum number of 10,000 trees was produced, at which point the search was limited and the 10,000 trees saved were swapped. Strict consensus and majority-rule consensus trees were calculated for the 10,000 equally parsimonious trees. Trees were rooted using the outgroup taxa (Maddison et al. 1984).

To test the support for nodes in the tree, both bootstrap (Felsenstein 1985) and jackknife (Farris et al. 1996) values were calculated in PAUP*. Bootstrap analysis was carried out with 1,000 replicates, TBR branch swapping and a limit of 1,000 trees per replicate. To calculate jackknife values, the 'Jac' emulation as implemented in PAUP* was performed with 100,000 replicates and 37% deletion, using the fast heuristic search option.

Results

Sequences

Sequences were obtained for 69 species of Pomaderreae and five outgroup species from related tribes. Two accessions were obtained for each of six taxa to test infraspecific variation: *Cryptandra amara*, *C. mutila*, *Siegfriedia darwinioides*, *Spyridium globulosum*, *Sp. parvifolium* and *Trymalium ledifolium*. The sequence variation between two sequences of the same species was ≤1.6% in all cases and in some cases, sequences were identical. Because of the low sequence variation, only a single sequence of each species, the first listed in Appendix 1, was used in the analysis of the *trn*L-F sequence data.

Large indels

In the alignment of the *trn*L-F sequences, several large indels were identified. In particular, one deletion of approximately 125 base pairs (indel no. 9) seemed to have occurred in unrelated species, a result revealed in the first analysis (A). Subsequently two more analyses were undertaken to explore the effect of indel no. 9 on the resulting topology of the tree. The following analyses of the *trn*L-F data-set were carried out:

Analysis A included all species and characters;

Analysis B excluded two of the three sequences with indel no. 9, namely those of *Pomaderris rotundifolia* and *Cryptandra triplex*, but included all characters;

Analysis C included all species, but excluded the DNA region in which indel no. 9 occurred, and all potential characters therein (following Quandt et al. 2004; see below for discussion).

Characteristics of sequences & phylogeny

The alignment of the *trn*L-F data set had 1145 base positions. Four regions in the alignment were ambiguous and unalignable and therefore excluded from the analysis. This reduced the data-set by 46 characters to 1099 base positions. Twenty-three indels were identified in the alignment and coded separately using the simple indel coding method of Simmons and Ochoterena (2000).

When all species and all characters were included in analysis A, the alignment provided 90 parsimony-informative characters (8.2%) and 21 out of 23 indel characters were potentially informative characters. In analysis B, the number of parsimony-informative characters in the alignment was reduced due to the exclusion of two species: 87 base characters (7.9%) and 20 of 23 the indels were potentially informative. Analysis C excluded a stretch of 261 bases from the alignment and reduced the number of characters to 838 base positions; this also eliminated 8 indel characters from the data-set. Analysis C included 67 potentially informative base characters (8.0 %), and 13 parsimony-informative indels.

In all three parsimony analyses, the maximum number of 10,000 trees was reached when using the two step search strategy. The trees of analysis A had a CI=0.566 and RI=0.789. The CI and RI for analysis B were 0.564 and 0.786, respectively. The trees in analysis C had a CI=0.572 and a RI=0.805. The strict consensus tree of analysis A (Fig. 1) showed 30 nodes common to all most parsimonious trees (27 nodes common to the ingroup); 23 nodes had bootstrap support (BS) and 22 nodes had jackknife support (JS) ≥50%. The strict consensus of analysis B (excluding the sequences containing indel no. 9; Fig. 2), had 28 nodes (25 nodes in the ingroup), of which 21 had bootstrap support and 20 nodes had jackknife support above 50%. Analysis C had 24 nodes present in the strict consensus tree (22 nodes in the ingroup; Fig. 3), statistical support ≥50% in the bootstrap and jackknife analyses was obtained for 19 nodes.

Cladogram topology

The strict consensus trees for analyses A and B are shown in Figures 1 and 2. Tree topology is the same in both cladograms, except that in analysis A the species containing indel no. 9 are grouped in one clade within the genus *Trymalium*. This clade is indicated in bold in Figure 1. Bootstrap (BS) and jackknife (JS) values differ only slightly between the analyses. The strict consensus in analysis C (Fig. 3) has a similar topology to the previous two trees, but is less resolved. However, the genus *Spyridium* was resolved in one clade (at node 3) in analysis C, and *Blackallia connata* grouped with *Cryptandra* (node 24) and not with *Stenanthemum gracilipes*, *St. grandiflorum* ms and *B. biloba* (clade at node 22). Only the tree in Figure 2 (analysis B) is discussed in the following sections and Figure 1 and 3 are only referred to when there are differences between the analyses.

Monophyly of the tribe Pomaderreae is very strongly supported with 100% bootstrap and jackknife support. Sister to Pomaderreae is either *Schistocarpaea johnsonii* (not placed in any tribe by Richardson et al. 2000b), *Adolphia californica* (tribe Colletieae), or a weakly supported clade (BS: 57%; JS: <50%) containing *Alphitonia* aff. *incana* (unplaced genus), *Ceanothus coeruleus* (unplaced genus) and *Phylica buxifolia* (tribe Phyliceae).

The backbone of the cladogram lacks bootstrap or jackknife support above 50% and thus the relationships among the main clades (genera) are unresolved. Of the currently accepted genera, only *Cryptandra* and two clades of *Stenanthemum* have bootstrap/jackknife support. The species of *Spyridium* do not group in a clade in the strict consensus tree in analyses A and B. However, they form a clade in 94% of trees in a majority rule consensus tree (majority rule tree not shown). In analysis C the species of *Spyridium* are united in a clade, albeit without bootstrap or jackknife support above 50%.

Within *Spyridium*, three species from New South Wales (*Sp. scortechinii*, *Sp. buxifolium* and *Sp. burragorang*) form a weakly supported clade at node 4. The two Tasmanian species included, *Sp. ulicinum* and *Sp. gunnii*, are sister taxa (node 6; BS: 61%, JS: 58%). *Spyridium mucronatum* and *Sp. cordatum* are strongly supported as sister taxa (node 7), but their relationship with the third Western Australian species included, *Sp. globulosum*, is unresolved. *Spyridium daltonii* and *S.* ×*ramosissimum* from the

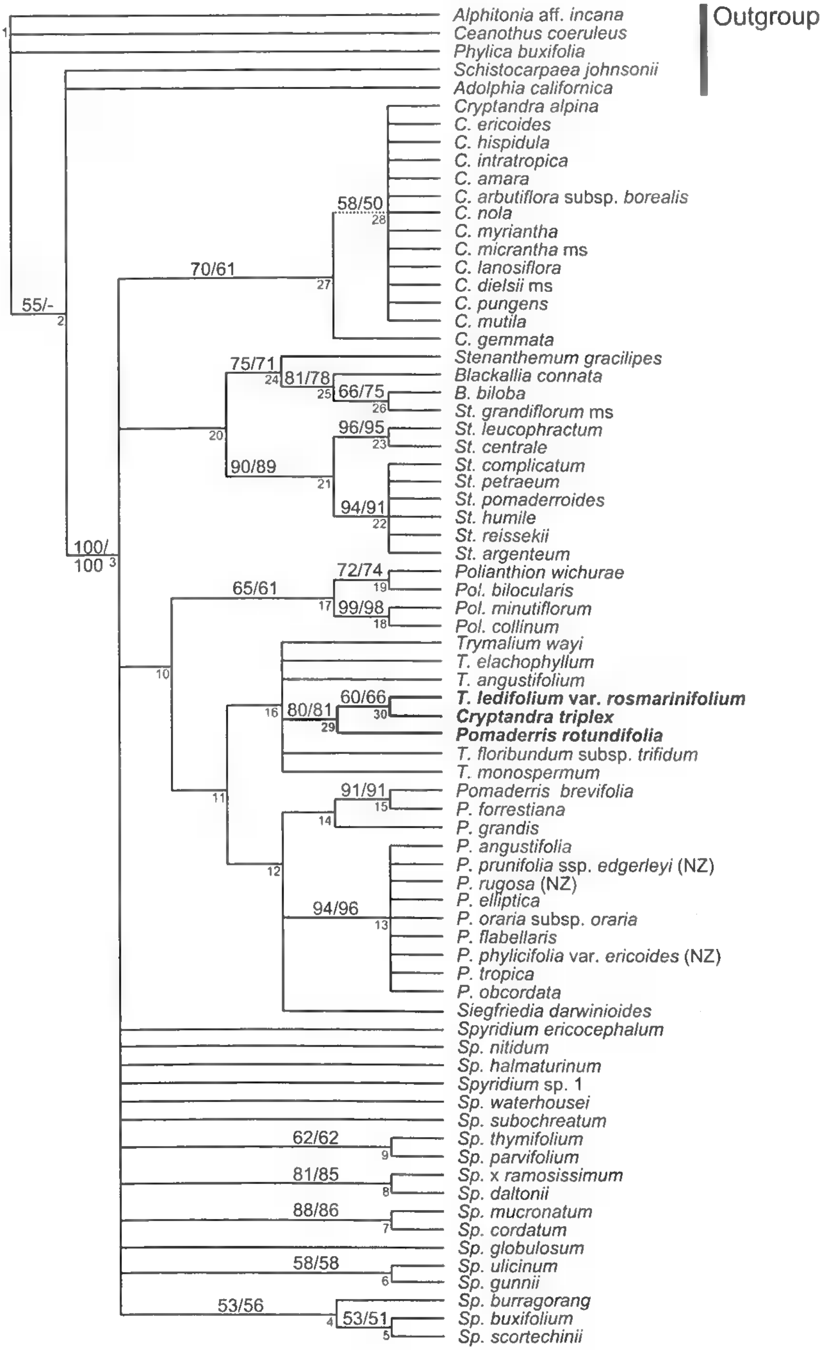

Fig. 1. Strict consensus tree of analysis A of the *trn*L-F data-set (10,000 equally parsimonious trees of 226 steps each, CI=0.57, RI=0.79), i.e., analysis of the full data-set. Bootstrap/jackknife values are indicated on branches. Node numbers are indicated in smaller type. The clade highlighted in bold contains taxa that share indel no. 9. The branch denoted by a dotted line is only present in bootstrap and jackknife analyses. Species from New Zealand are indicated (NZ).

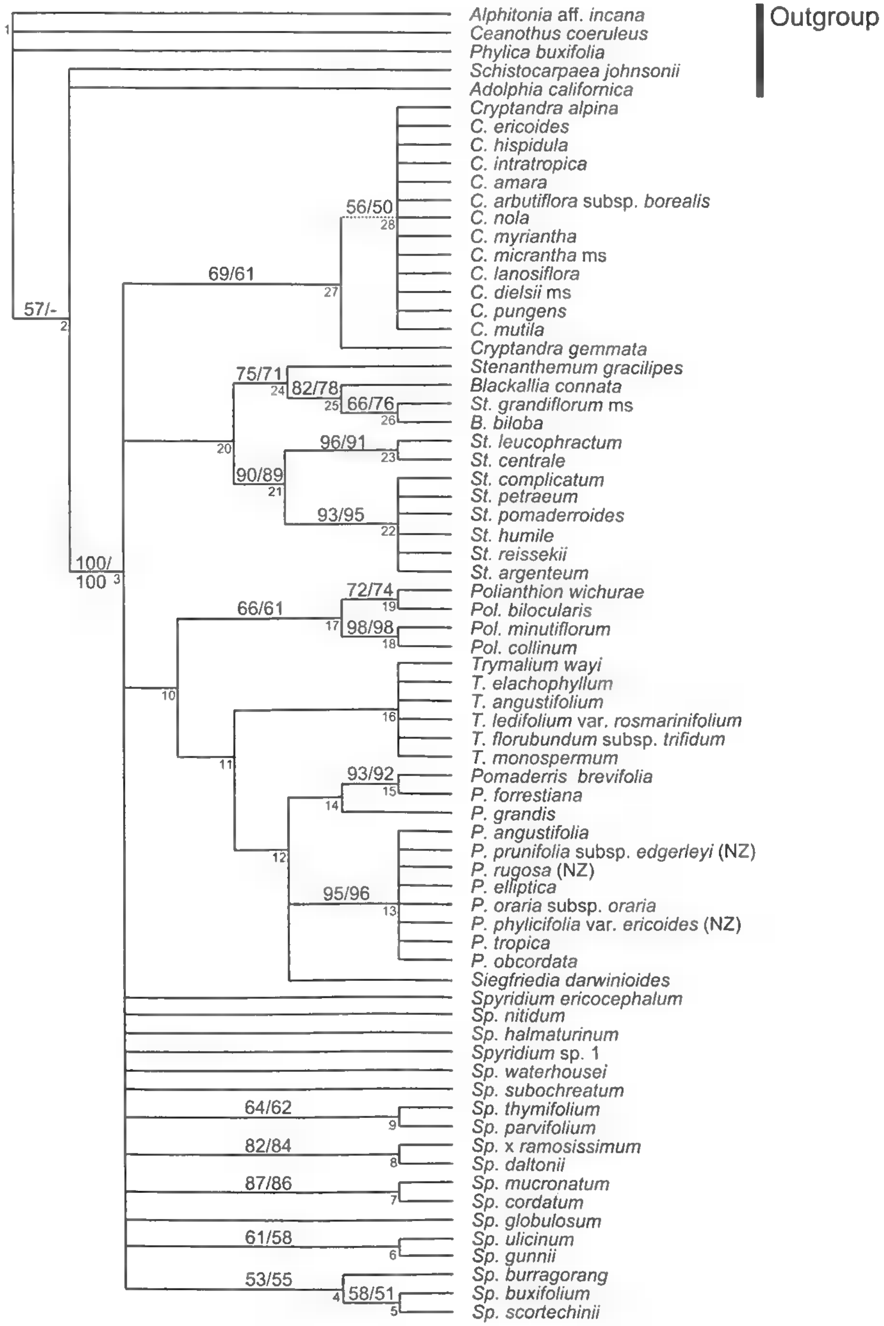

Fig. 2. Strict consensus tree of analysis B of the *trn*L-F data-set (10,000 equally parsimonious trees of 220 steps each, CI=0.56, RI=0.79), i.e., parsimony analysis excluding sequences from two taxa with indel no. 9 (*Pomaderris rotundifolia, Cryptandra triplex*). Bootstrap/jackknife values are indicated on branches. Node numbers are indicated in smaller type. The branch denoted by a dotted line is only present in bootstrap and jackknife analyses. Species from New Zealand are indicated (NZ).

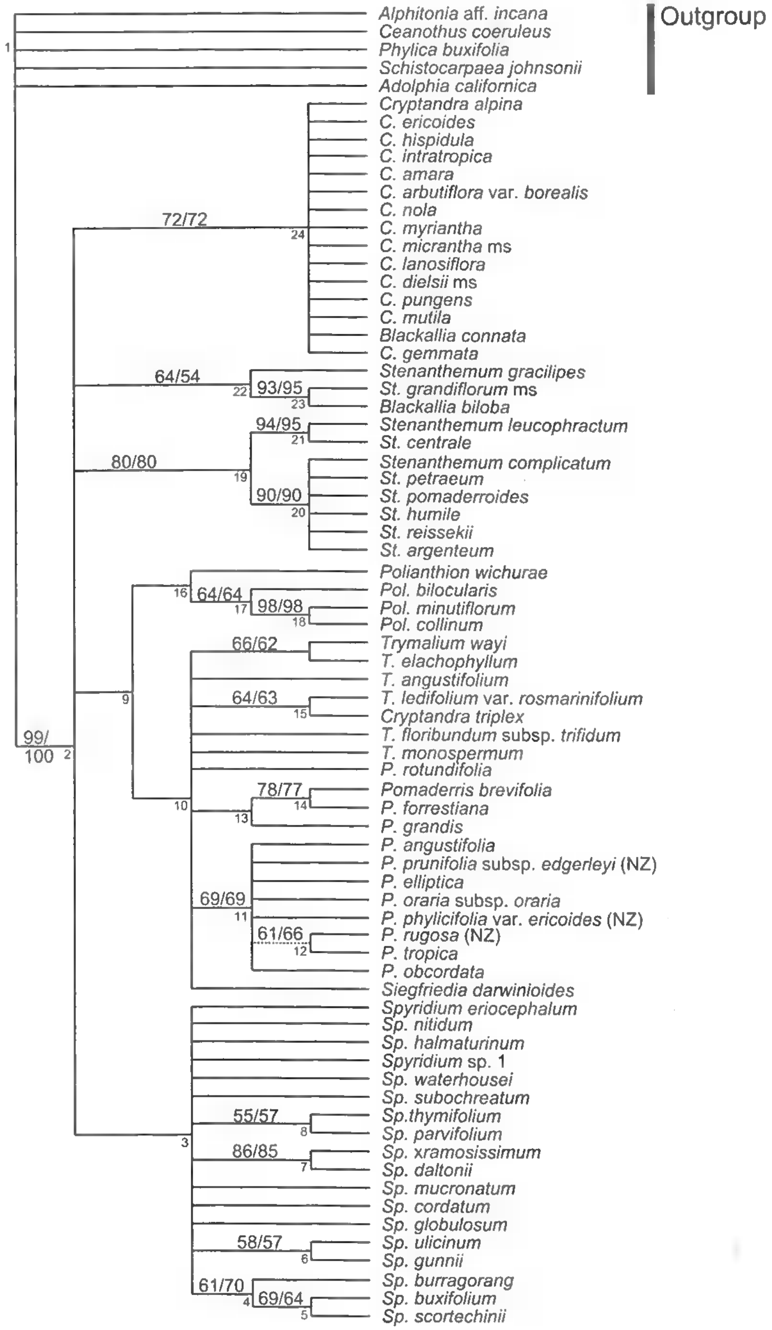

Fig. 3. Strict consensus tree of analysis C of the *trn*L-F data-set (10,000 equally parsimonious trees of 259 steps each, CI=0.57, RI=0.81), i.e., parsimony analysis excluding the DNA region containing indel no. 9. Bootstrap/jackknife values are indicated on branches. Node numbers are indicated in smaller type. The branch denoted by a dotted line is only present in bootstrap and jackknife analyses. Species from New Zealand are indicated (NZ).

Grampians, Victoria, form a strongly supported clade at node 8 (BS: 82%, JS: 84%). *Spyridium parvifolium* and *Sp. thymifolium* from south-eastern Australia are sister taxa (node 9 with moderate support).

Siegfriedia darwinioides and two clades of *Pomaderris* form a trichotomy at node 12, which lacks support. Species of *Pomaderris* from south-eastern Australia and New Zealand group in one strongly supported clade (node 13), while the Western Australian species, *P. brevifolia*, *P. forrestiana* and *P. grandis*, form a second unsupported clade (node 14). Within the clade the relationship of *P. brevifolia* and *P. forrestiana* is strongly supported. Sister to the *Siegfriedia-Pomaderris* clade is a clade that contains *Trymalium* species from Western Australia and South Australia (*T. wayi*). The *Trymalium* clade does not receive support >50% and shows no internal resolution.

If the two species that share indel no. 9 with *Trymalium ledifolium*, *Pomaderris rotundifolia* (W.A.) and *Cryptandra triplex* (N.T.), are included, then these three species form a well supported sub-clade within *Trymalium* (Fig. 1, node 29; BS: 80%, JS 81%). *Pomaderris rotundifolia* is sister to the other two species.

In analysis C, *Siegfriedia*, *Trymalium* and the two *Pomaderris* clades form a big polytomy (Fig. 3, node 10) in which only a few relationships are resolved, such as the sister-relationship of *P. rugosa* from New Zealand with *P. tropica* (Qld), and the grouping of *T. ledifolium* with *Cryptandra triplex*. In analysis C, *P. rotundifolia* does not group with either of the two *Pomaderris* clades.

The sister-group to the *Pomaderris-Siegfriedia-Trymalium* clade is the genus *Polianthion*, the four species of which group in a moderately supported clade at node 17 (Fig. 2; BS: 66%, JS: 61%) that consists of two well supported sub-clades (nodes 18 and 19). Two species from south-western Western Australia, *Pol. wichurae* and *Pol. bilocularis*, group in the first sub-clade; *Pol. minutifolium* from Queensland and *Pol. collinum* (W.A.) form the second sub-clade. In analysis C, *Pol. wichurae* is sister to the remaining three species (Fig. 3, node 16); this topology, however does not receive statistical support.

The genus *Stenanthemum* sensu stricto (according to Rye 1995, 2001 and Thiele 2007) is found at node 21 with high bootstrap and jackknife percentages (≥89 %). It is divided further into two highly supported groups. One clade at node 23 contains species from southern (*St. leucophractum*) and central Australia (*St. centrale*); the second clade (node 22) shows no internal resolution and contains five species from Western Australia and the only representative of the genus in Queensland, *St. argenteum*.

A group of four species from Western Australia is the sister group to *Stenanthemum* s. str. (node 24); the relationships between all four species are moderately to highly supported. *Stenanthemum gracilipes* is sister to the remaining species (BS: 75%, JS: 71%), namely *Blackallia connata*, *B. biloba* and *St. grandiflorum* ms. The two species of *Blackallia*, however, are not sister taxa, with *B. biloba* most closely related to *St. grandiflorum* ms (BS: 66%, JS: 76%). *Blackallia connata* is not part of this clade in analysis C, but is part of the *Cryptandra* clade (Fig. 3, node 24).

Fourteen species of *Cryptandra* form a large polytomy in the strict consensus tree (Fig. 2, node 27). This clade receives moderate support with bootstrap and jackknife values ≥61%. In analyses A and B, *C. gemmata* from Arnhem Land (N.T.) is sister to all remaining species, but this relationship is only resolved in the bootstrap and jackknife trees, not in the strict consensus tree (BS: 56%; JS: 50%). As stated previously, *Blackallia connata* is placed in *Cryptandra* in analysis C.

Discussion

Overall characteristics of the *trn*L-F region

The analysis of the *trn*L-F sequence data resulted in a less resolved tree, when compared with the tree generated from ITS data (Kellermann et al. 2005). This is mainly due to fewer informative base and indel characters. The *trn*L-F data-set contained 110 potentially informative characters, with the ITS region providing 270 informative characters, i.e., more than double the number in a shorter region of DNA. However, the CI and RI were higher in the *trn*L-F analyses, indicating less character conflict.

This paucity of informative characters reflects the fact that chloroplast DNA evolves slower than nuclear DNA and that "even non-coding cpDNA regions often fail to provide significant phylogenetic information at low taxonomic levels" (Small et al. 2004, p. 147). The cpDNA region *trn*L-F provides resolution mainly at the generic level in this analysis. This region neither provides much information about the relationships between genera of Pomaderreae nor resolves the clades well within genera.

Homoplasious indels

A conspicuous feature of the *trn*L-F region during alignment and analysis was the presence of two large indels in the *trn*L intron, namely a deletion between bases 380–576 in the alignment (indel no. 9; c. 125 bp) and a deletion between bases 443–487 (indel no. 11, c. 45 bp).

Indel no. 9 groups *Trymalium ledifolium*, *Pomaderris rotundifolia* and *Cryptandra triplex* in analysis A (clade at node 29). This relationship is also supported by a base change from A to G at position 660 in the alignment, which is unique to these species. Results from the analysis of ITS sequences do not support this clade, since they place *C. triplex* into *Cryptandra* and *P. rotundifolia* with its congeners into a clade of *Pomaderris* species from Western Australia. An error during lab-work or cross-contamination of samples can be ruled out, since the DNA extraction of these species and the PCR reactions were done at separate times. In addition, Richardson et al. (2000a) also reported this long indel in their sequence of *T. ledifolium*; our sequence is identical to that of Richardson and co-workers, with the exception of two deletions of a single nucleotide towards the 3' end of the sequence (base positions 1194 and 1198).

Indel no. 11 occurs in *Spyridium buxifolium*, *Siegfriedia darwinioides*, *Stenanthemum gracilipes*, *St. grandiflorum* ms, *Blackallia connata* and *B. biloba*. However, some of these species are clearly not related, and in the resulting trees of analyses A and B (Fig. 1 & 2) some are not grouped together: *Spyridium buxifolium* is related to *Sp. burragorang* and *Sp. scortechinii* (node 4), *Si. darwinioides* is most closely related to *Pomaderris* (node 12) and the four-taxon clade at node 24 is the sister group to *Stenanthemum* (node 21). In analysis C, *B. connata* is part of the *Cryptandra* clade (Fig. 3, node 24). It is obvious from these results, that indel no. 11 is a homoplasious character and cannot be relied upon for the correct delimitation of relationships. This is corroborated by the placement of these species in the ITS analysis (Kellermann et al. 2005).

The *trn*L intron, in which both long indels occur, is part of the Group I Intron family and its RNA has a conserved secondary structure (Borsch et al. 2003; Cech 1988; Quandt et al. 2004). This complex structure consists of several stem-loop regions and paired sequence elements. Borsch et al. (2003, p. 565) have shown that in angiosperms "the P6 and P8 stem-loop regions account for most of the sequence length variation in the [*trn*L] intron" and can contain highly variable regions. Although a detailed modelling of the secondary structure of the *trn*L intron has not been attempted here, it is possible to map most of the conserved regions of Group I Introns by simple sequence comparison. Using the secondary structure of *Nymphaea odorata* Ait. (Borsch et al. 2003, Fig. 2) as a model, it can be deduced that indels no. 9 and no. 11 are indeed located within the P8 stem-loop region. Indel no. 9 nearly encompasses the whole P8 region. It is therefore most likely that these indels are the result of a loss of an arm, stem or loop from the P8 stem-loop region. Homoplasious indels in analyses of non-coding regions of cpDNA have been reported by Morton & Clegg (1993), Mes et al. (2000) and others, who concluded that homplasious indels can be associated with hairpin structures.

In a phylogeny of land plants, Quandt et al. (2004) excluded the P8 region from the analysis, since it was not alignable across the species in the data-set and was assumed to be not even homologous across all lineages. These authors recommend the exclusion of P8, and possibly P6, in studies of higher level phylogenies. This advice was followed in analysis C, where the P8 region was not included.

The homoplasious indels in Pomaderreae could have been created several times independently, for example in the particularly labile P8 region, which could easily lose a hairpin or stem-loop region. Alternatively, if these homoplasious indels originated only once, they must have been transferred to these species through the introgression of a chloroplast genome containing the indels from one species to another (Rieseberg & Brunsfeld 1992).

The first possibility seems likely in the case of indel no. 11, which appears independently in at least three lineages: *Siegfriedia darwinioides*, *Spyridium buxifolium*, the clade at node 24, and possibly *Blackallia connata*, if it is part of *Cryptandra* as suggested by analysis C and the ITS sequence analysis (Kellermann et al. 2005).

The case is equivocal for indel no. 9. The presence of additional supporting characters for clade 29, namely a base change from A to G at position 660 in the alignment, a common base change from C to A (position 1132) in *Trymalium ledifolium* and *Cryptandra triplex*, and the fact that the three species in that clade share an insertion with *T. elachophyllum* and *T. angustifolium* (indel no. 8, positions 355–362 in the alignment), suggest a possible single origin of indel no. 9. On the other hand, the sequence of *Pomaderris rotundifolia* shares a base change from C to G (position 836) with all species of *Pomaderris* and *Siegfriedia*, as well as a base change from A to C (position 806) with *P. forrestiana*, which is the sister taxon of *P. rotundifolia* in the ITS sequence analysis (Kellermann et al. 2005). The latter two base changes clearly show a relationship of *P. rotundifolia* with *Pomaderris* and not with *Trymalium* and would indicate that indel no. 9 is homoplasious. Flower morphology also supports a relationship of *P. rotundifolia* with *Pomaderris* (Walsh & Coates 1997) and of *C. triplex* with *Cryptandra* (Kellermann 2006a).

Since the region in which indels no. 9 and no. 11 occur is part of the highly variable P8 region, which is prone to homoplasious indels, the possibility of more homplasious characters cannot be ruled out, in particular in this region. As such, a phylogenetic analysis C, excluding the region, might be the best representation of the relationships in Pomaderreae, a fact that is corroborated in some degree by slightly higher CI and RI values for analysis C.

Pomaderreae

The tribe Pomaderreae is monophyletic and supported with very high bootstrap and jackknife percentages. This confirms the results of the ITS data-set (Kellermann et al. 2005) and of previous analyses, using combinations of *trn*L-F and *rbc*L sequence data (Fay et al. 2001; Richardson et al. 2000a) and *trn*L-F/ITS sequences (Richardson et al. 2001; Islam & Simmons 2006). The sister group to Pomaderreae, however, is unclear from the results of the *trn*L-F data-set. In previous analyses, either *Ceanothus* or the tribe Colletieae (Richardson et al. 2000a), or the genera *Alphitonia* and *Granitites* (Fay et al. 2001) were the closest relatives to Pomaderreae. Islam & Simmons (2006) also reported *Alphitonia* as the weakly to moderately supported sister group to Pomaderreae when analysing combined molecular and morphological data-sets. The results of Kellermann et al. (2005) indicated with weak support that Colletieae (represented by *Adolphia*) might be the sister taxon to Pomaderreae.

Spyridium

Species of *Spyridium* do not form a clade in the strict consensus trees in analyses A and B. However, they group together in 94% of most parsimonious trees in these analyses (majority rule tree not shown) and in analysis C. Within *Spyridium*, several species form small clades that are moderately to well supported. A clade of closely related species from New South Wales, *Sp. scortechinii* and relatives (node 4), and a clade of Tasmanian species (*Sp. ulicinum* and *Sp. gunnii*, node 6) were found also in the ITS analysis. This corroborates the unique position of *Sp. scortechinii* and relatives in the genus; they are the only species of *Spyridium* in New South Wales with a very long hypanthium tube (Thiele & West 2004), which was the reason these species were not included in *Spyridium* for a long time. This feature also occurs in *Sp. waterhousei* (S.A.), a species that was recently transferred back into *Spyridium* (Kellermann 2007). *Spyridium mucronatum* and *Sp. cordatum* from Western Australia form a well supported clade (node 7), but the position of the third western species, *Sp. globulosum*, was unresolved. The ITS data-set groups *Sp. mucronatum* and *Sp. globulosum* species into one clade (*Sp. cordatum* was not included in the ITS analysis). The remaining species from south-eastern Australia do not group together, as they do in the ITS results (Kellermann et al. 2005), but form a polytomy. The chloroplast data-set also confirms the close relationship of *Sp. daltonii* and *Sp.* ×*ramosissimum* (node 8) and corroborates previous findings that these species were misplaced in *Trymalium* (Kellermann 2006b).

The poor result for *Spyridium* is caused by both a conflict of characters and lack of informative characters for the group. There is only one synapomorphy for the genus as a whole, a base change from A to G (position 869). In analysis A and B this phylogenetic signal is in conflict with other base changes that occur in the region of indel no. 9. Once this DNA region is excluded (analysis C), species of *Spyridium* group in one clade. Overall, the results for *Spyridium* are not in conflict with the ITS analysis

Pomaderris and *Siegfriedia*

Pomaderris is divided into two geographically separated clades that form a trichotomy (node 12) with *Siegfriedia darwinioides*. This highlights the close relationship of *Siegfriedia* and *Pomaderris*, which is corroborated by ITS data (Kellermann et al. 2003) and morphology: both genera have a basal valve in each fruitlet of their schizocarpic fruits (Rye 1996b).

The two *Pomaderris* clades contain species from Western Australia (node 14) and south-eastern Australia (including New Zealand; node 13), respectively. The clade at node 14 is not supported, only the relationship between *P. forrestiana* and *P. brevifolia* is highly supported. All Western Australian species share a deletion of five bases (indel no. 5, bp 161–164 in the alignment). They have been perceived as distinct from the remaining species of *Pomaderris* before (N.G. Walsh, pers. comm.), because of their umbellate (or contracted) inflorescences and flowers with a very conspicuous annular disc (Rye 1996b). Most south-eastern Australian species (node 13) have a disc that is inconspicuous or absent. *Pomaderris obcordata* from mallee scrubland in South Australia and Victoria is part of this clade, and not, as in the ITS analysis, at the base of *Pomaderris*. It is, however, anomalous in the genus, because of the absence of a clearly defined valve in the fruitlets. A few other species from *Pomaderris* sect. *Apetalae* N.G.Walsh, sect. *Flabellares* N.G.Walsh and sect. *Psilogyne* N.G.Walsh may not have a clearly defined valve as well (Walsh & Coates 1997). The south-eastern Australian clade receives high support, but relationships within it are not resolved.

Trymalium

The sister group to the *Siegfriedia-Pomaderris* clade is a clade that contains species of *Trymalium* from Western Australia and South Australia (node 16). This relationship, however, does not receive statistical support ≥50%; its synapomorphy is one unique base change at position 878 in the alignment (C to G). When *Pomaderris rotundifolia* and *Cryptandra triplex* are included (analysis A) they form a clade with *Trymalium ledifolium* (Fig. 1, node 29), as discussed above. Morphologically, *P. rotundifolia* displays characters typical for *Pomaderris*, such as the basal valve in each fruitlet, a deeply divided style, and a densely hairy ovary summit (Rye 1996b). It differs from other species of *Pomaderris* in its unique, compact, head-like inflorescences and flowers with more strongly hooded petals. Morphologically, *C. triplex* seems to be very similar to two species of *Cryptandra* from northern Australia (Kellermann 2006a): *C. filiformis* A.R.Bean (not included in this analysis) and *C. intratropica* W.Fitzg. The three species share dense indumentum on all parts of the plant. *Cryptandra intratropica* and *C. triplex* were included in the ITS analysis and are nested deep within *Cryptandra* in a clade of northern species (node 52 in Kellermann et al. 2005, Fig. 1). The presence of stipules that are fused around the base of the petiole and a ring of bracts at the base of the flower are important morphological characters (Thiele & West 2004) that indicate a relationship of *C. triplex* with *Cryptandra*. The cpDNA characters that place these two species into *Trymalium* seem to be homoplasious indels and base changes.

Polianthion

The clade at node 17 unites four species that were labelled as the 'Bilocular Clade' by Kellermann et al. (2005) and have since been described as the new genus *Polianthion* (Kellermann et al. 2006). It is well supported and consists of two species pairs: *Pol. minutiflorum* groups with *Pol. collinum* (node 18; JS/BS: 98%), and *Pol. bilocularis* with *Pol. wichurae* (node 19; JS/BS: ≥72%). The same relationships were reported by Kellermann et al. (2005), and are corroborated with this cpDNA data-set. The four species share a biloculate ovary and a conspicuous dense indumentum on all surfaces of the plant. The clade is here sister to *Pomaderris*, *Siegfriedia* and *Trymalium*. All species in these genera share a 1 bp deletion (indel no. 20, position 1088), but the relationship does not receive bootstrap or jackknife support above 50%. Kellermann et al. (2005) report an association of *Polianthion* with *Cryptandra*, *Blackallia biloba* and *Stenanthemum grandiflorum* ms, but this too did not receive statistical support.

Stenanthemum

Three species currently included in *Stenanthemum*, namely *St. gracilipes*, *St. grandiflorum* ms and *St. intropubens* Rye ms (the last species not included in this analysis) are in conflict with the definition of the genus (Rye 1995, 2001; Thiele 2007), since they do not share typical morphological characters, such as a disc that is lining the hypanthium tube. Two strongly supported clades containing species of *Stenanthemum* s. str. (i.e., according to Rye and Thiele) from south-eastern and central Australia (SE-central clade, node 23) and Western Australia and Queensland (WA-Qld clade, node 22) are sister-taxa in the *trn*L-F analysis (node 21; BS/JS: ≥89%). This confirms the monophyly of *Stenanthemum* s. str. These two clades were also found in the ITS results. The atypical species included in the analysis, *St. grandiflorum* ms and *St. gracilipes*, appear in the clade at node 24 (see below). This is in contrast to the results of Kellermann et al. (2005), which placed *St. gracilipes* as sister taxon to the WA-Qld clade with low support (node 35 in Kellermann et al. 2005: BS: 53%, JS: 57%).

Species associated with *Stenanthemum*

The clade at node 24 that is shown as sister to *Stenanthemum*, contains four species, which are very different in appearance and habit: *St. gracilipes*, *Blackallia connata*, *St. grandiflorum* ms and *B. biloba*.

This clade contradicts the results from the ITS data (Kellermann et al. 2005), in which *Blackallia connata* is placed into *Cryptandra* and *St. gracilipes* into *Stenanthemum*. However, in analysis C, *B. connata* falls within a well supported *Cryptandra*, thus agreeing with the ITS results. The homoplasious nature of some indels in the P8 stem-loop region of the *trn*L intron has been discussed above. All characters that unite *B. connata* with these other three species are located within the P8 region, and this grouping might therefore be an artefact of an incorrect phylogenetic signal caused by homoplasious indels (see also Quandt et al. 2004). Once the P8 region is excluded from the analysis, the results also agree with morphology. *Blackallia connata* has single, sessile flowers that are surrounded by rows of bracts and contain a pubescent disc that surrounds the ovary; the stipules are connate below the attachment point of the petiole. These and other features of the species are typical for *Cryptandra* (Thiele & West 2004, Thiele 2007).

The three remaining species in the clade have glabrous discs surrounding the ovary, and a simple cymose inflorescence; stipules are free from one another or connate between petiole and stem. In *Stenanthemum gracilipes* and *Blackallia biloba* the flowers have long pedicels. These characters are at odds with the placement of *St. gracilipes* in the *Stenanthemum* clade in Kellermann et al. (2005), since putative synapomorphies for *Stenanthemum* s. str. are a disc that is adnate to the hypanthium tube and sometimes confluent with the filament bases, and dense cymose heads with sessile flowers (Rye 1995, 2001; Thiele 2007).

Stenanthemum grandiflorum ms is resolved as the sister taxon to *Blackallia biloba* in both the *trn*L-F and ITS analyses. An unnamed species, *St. intropubens* ms (not included in the analysis), is similar to *St. grandiflorum*. Although *B. biloba* shares long-pedicellate flowers with *St. gracilipes*, its flower morphology and habit are distinct from *St. gracilipes*, *St. grandiflorum* ms and *St. intropubens* ms.

Stenanthemum gracilipes has long been seen as a unique species with no apparent close relatives and these results strongly suggest the recognition of a monotypic genus for this species. A new genus containing *St. grandiflorum* ms and *St. intropubens* ms is also supported by our results and was already recommended by Kellermann et al. (2005) as 'New genus A'. The description of these new genera will be published in the near future, in addition to a new circumscription of *Blackallia* (Kellermann et al., in press).

Cryptandra

All remaining species of *Cryptandra* fall into one clade. However, there is no resolution within that clade, with the exception of *C. gemmata*, which is sister to the remaining species in the jackknife and bootstrap trees, but not in the strict consensus tree. Synapomorphies for the genus *Cryptandra* were mentioned above and comprise stipules that are connate at the base of the petiole, single flowers, surrounded by row(s) of bracts, a pubescent annular disc around the base of the ovary and schizocarpic fruits that release dehiscent fruitlets (Thiele & West 2004, Thiele 2007). *Cryptandra gemmata* is unique in the genus since it is apparently the only species with truly terminal inflorescences (Bean 2004); it is also one of very few species of *Cryptandra* to occur in the tropical north of Australia (Kellermann 2006a). Some of these tropical species fall into one clade in the analysis of Kellermann et al. (2005, clade at node 52).

Conclusions

The analysis of DNA sequence data from the chloroplast *trn*L-F region confirmed most findings of the ITS data-set (Kellermann et al. 2005). However, it was hampered by the lack of informative characters and the presence of apparently homoplasious indel characters and base changes within the P8 region of the *trn*L intron. As such, the strict consensus tree of the *trn*L-F analysis was less resolved and had fewer supported clades than in the ITS analysis.

The genera *Cryptandra*, *Stenanthemum* and *Polianthion* were well supported. Species of *Trymalium* from Western Australia and South Australia formed one clade, but when two taxa with a large homoplasious indel (no. 9), *P. rotundifolia* and *C. triplex*, were included in the analysis they appeared in the *Trymalium* clade. This was also in contrast to the ITS results. *Pomaderris* was divided into a Western Australian clade and a clade containing south-eastern Australian species; these two clades formed an unresolved trichotomy with the monotypic *Siegfriedia*. *Stenanthemum grandiflorum* ms and *Blackallia biloba* are confirmed as closely related species. Their sister taxon is *B. connata*, with *St. gracilipes* next in the phylogenetic sequence, when the P8 region is included in the analysis. When the region is excluded, *B. connata* changes its position and moves into the *Cryptandra* clade, a result that is supported both by morphology and ITS sequence data. All species of *Spyridium* do not group in a clade, but are resolved in a polytomy at the base of Pomaderreae with the clades described above. If the P8 region is excluded, they form a clade, albeit without statistical support.

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Appendix 1. Sources of plant material used for sequencing of *trn*L-F DNA regions. All samples were collected in Australia, except where indicated. GenBank accessions in bold indicate sequences obtained for this project. ANBG: Australian National Botanic Gardens, Canberra; cult.: plant collected from cultivation; NSW: New South Wales; N.P.: National Park; NT: Northern Territory; Qld: Queensland; RBG: Royal Botanic Gardens, Melbourne; SA: South Australia; Tas.: Tasmania; Vic.: Victoria; WA: Western Australia. Standard herbarium abbreviations according to Holmgren et al. (1990).

Species	**Locality**	**Voucher/citation**	**Material type /date of collection**	**GenBank accession No.**
OUTGROUP				
Adolphia infesta Meisn.	USA: California	Aagesen et al. (2005)		AY460408 AY642142
Alphitonia aff. *incana* (Roxb.) Kurz	Australia	Richardson et al. (2000a) (as *Alphitonia excelsa* Reissek)		AJ390352
Ceanothus coeruleus Lag.	USA: California	Thulin et al. (1998)		AJ225798
Phylica buxifolia L.	South Africa	Richardson et al. (2001)		AF327614
Schistocarpaea johnsonii F.Muell.	Australia	Richardson et al. (2000a)		AJ390349
INGROUP				
Blackallia biloba C.A.Gardner	WA: Northampton	*J. Kellermann 257* (MEL)	fresh; 2001	**EF528505**
B. connata (C.A.Gardner) C.A.Gardner	WA: Laverton Downs Station	*H. Pringle 2494* (CANB)	herb.; 1989	**EF528503**
Cryptandra alpina Hook.f.	ANBG B8903607 Sect. 231	*R. Burns 98* (CBG at CANB)	silica; 2003	**EF528488**
C. amara Sm. **1**	N.G.Walsh (cult.)	*N.G. Walsh s.n.* (MEL)	fresh; 2000	**EF528489**
C. amara Sm. **2**	NSW: Nimmitabel	Rosetto et al. (2001)		AF300321
C. arbutiflora var. *borealis* Rye	WA: N of Geraldton	*J. Kellermann 224* (MEL)	fresh; 2001	**EF528491**
C. dielsii C.A.Gardner ms	WA: Trayning-Kellerberrin Rd	*J. Kellermann 292* (MEL)	fresh; 2001	**EF528500**
C. ericioides Sm.	NSW: Saltwater Creek	*D.E. Albrecht* 3989 (MEL)	herb.; 1990	**EF528487**
C. hispidula Reissek & F.Muell. ex Reissek	SA: Kangaroo Island	*G. Jackson 3187* (MEL)	herb.; 1994	**EF528492**
C. intratropica W.Fitzg.	WA: King Edward River	*L.A. Craven & C.L. Brubaker 9163* (CANB)	herb; 1983	**EF528495**
C. lanosiflora F.Muell.	ANBG 617457 Sect. 99F	*S. Fethers 8* et al. (CANB)	silica; 2003	**EF528490**
C. micrantha Rye ms	WA: Wongan Hills	*J. Kellermann 287* (MEL)	fresh; 2001	**EF528493**
C. myriantha Diels	WA	Richardson et al. (2000a) (as *Cryptandra* cf. *spyridioides* F.Muell.)		AJ390360

C. mutila Nees ex Reissek **1**	WA: Singleton	*B. Keighery s.n.* (PERTH)	herb.; 1999	**EF528499**
C. mutila Nees ex Reissek **2**	WA	*M. Hislop 1068* (PERTH)	herb.; 1998	**EF528498**
C. nola Rye	WA: Pinjar	*B.L. Rye 239044* (PERTH)	herb.; 2003	**EF528496**
C. pungens Steud.	WA: Ravensthorpe	*J. Kellermann 375* (MEL)	fresh; 2001	**EF528497**
C. triplex K.R.Thiele ex Kellermann	NT: Jabiru East	*L.A. Craven 6546* (MEL)	herb.; 1981	**EF528549**
C. gemmata A. R. Bean	NT: SE of Oenpelli	*C. Dunlop 4919* (MEL)	herb.; 1978	**EF528494**
Polianthion bilocularis (A.S.George) Kellermann	WA: Dongolocking	*S. Patrick 394* (PERTH)	herb.; 1986	**EF528502**
Polianthion collinum Rye	WA: Yalgoo	*A. Chant 9* (PERTH)	herb.; 2000	**EF528511**
Pol. minutiflorum (E.M.Ross) K.R.Thiele	Qld: Coominglah State Forest	*A.R. Bean 9107 & G. Turpin* (CANB)	herb.; 1995	**EF528510**
Pol. wichurae (Nees ex Reissek) K.R.Thiele	WA: Hi Vallee Farm, Badgingarra	*J. Kellermann 183* (MEL)	fresh; 2001	**EF528501**
Pomaderris angustifolia N.A.Wakef.	N.G.Walsh (cult.)	*N.G. Walsh s.n.* (MEL)	fresh; 2000	**EF528518**
P. brevifolia N.G.Walsh	WA: Ravensthorpe	*J. Kellermann 388* (MEL)	silica; 2001	**EF528513**
P. elliptica Labill.	N.G.Walsh (cult.)	*N.G. Walsh s.n.* (MEL)	fresh; 2000	**EF528519**
P. forrestiana F.Muell.	WA: Mt Jimberiana	*B. Archer 2271* (MEL)	herb.; 2002	**EF528514**
P. grandis F.Muell.	WA: Mount Manypeaks	*N.G. Walsh 2776* (MEL)	herb.; 1989	**EF528512**
P. obcordata Fenzl	SA: Eyre Peninsula	*N.G. Walsh 3999* (MEL)	herb.; 1995	**EF528516**
P. oraria F.Muell. ex Reissek subsp. *oraria*	N.G.Walsh (cult.)	*N.G. Walsh s.n.* (MEL)	fresh; 2000	**EF528515**
P. prunifolia subsp. *edgerleyi* (Hook.f.) L.Moore	N.G.Walsh (cult.)	*N.G. Walsh s.n.* (MEL)	fresh; 2000	**EF528521**
P. phylicifolia var. *ericioides* Maiden & Betche	N.G.Walsh (cult.)	*N.G. Walsh s.n.* (MEL)	fresh; 2000	**EF528520**
P. rotundifolia (F.Muell.) Rye	WA: Ravensthorpe-Esperance area	*J. Kellermann 379* (MEL)	fresh; 2001	**EF528550**
P. rugosa Cheeseman	New Zealand	Richardson et al. (2000a)		AJ390363
P. tropica N.A.Wakef.	Qld: Walsh's Pyramid	*I.R. Telford 12045* (CBG at CANB)	herb.; 1994	**EF528517**
Siegfriedia darwinioides C.A.Gardner **1**	N.G.Walsh (cult.)	*N.G. Walsh s.n.* (MEL)	fresh; 2000	**EF528507**
Si. darwinioides C.A.Gardner **2**	WA	Richardson et al. (2000a)		AJ390375
Spyridium burragorang K.R.Thiele	ANBG c606176 Sect. 31	*S. Donaldson 903* (CBG at CANB)	silica; 2001	**EF528536**
Sp. buxifolium (Fenzl) K.R.Thiele	NSW: E of 'Boonara'	*J.R. Hosking 1848* (MEL)	herb.; 2000	**EF528508**
Sp. cordatum (Turcz.) Benth.	WA: Ravensthorpe	*J. Kellermann 370* (MEL)	fresh; 2001	**EF528530**
Sp. daltonii (F.Muell.) Kellermann	Vic.: Grampians	*J. Read s.n.* (MEL)	fresh; 2000	**EF528534**
Sp. eriocephalum Fenzl var. *eriocephalum*	ANBG 9106516 Sect. 100	*A.M. Lyne 675* (CBG at CANB)	silica; 2003	**EF528522**
Sp. globulosum (Labill.) Benth. **1**	WA: Dempster Head	*B. Archer 2255* (MEL)	silica; 2002	**EF528529**
Sp. globulosum (Labill.) Benth. **2**	WA	Richardson et al. (2000a)		AJ390358

Sp. gunii (Hook.f.) Benth.	ANBG 9902964 Sect. 99	*R. Burns 74* (CBG at CANB)	silica; 2003	**EF528524**
Sp. halmaturinum (F.Muell.) F.Muell.	ANBG 631019 Nursery	*J. Nightingale 143* (CANB)	silica; 2003	**EF528527**
Sp. mucronatum Rye	WA: Lake King	*J. Kellermann 367* (MEL)	silica; 2001	**EF528528**
Sp. nitidum N.A.Wakef.	SA: Kangaroo Island	*I. Jackson 3253* (MEL)	herb.; 1997	**EF528531**
Sp. parvifolium (Hook.) F.Muell. **1**	Melbourne University (cult.)	*J. Kellermann 112* (MEL)	fresh; 2001	**EF528526**
Sp. parvifolium (Hook.) F.Muell. **2**	Australia	Rossetto et al. (2001)		AF300322
Sp. ×ramosissimum (Audas) Kellermann	Vic.: Grampians	*J. Kellermann 122* (MEL)	silica; 2001	**EF528535**
Sp. scortechinii (F.Muell.) K.R.Thiele	Melbourne University (cult.)	*J. Kellermann 409* (MEL)	fresh; 2002	**EF528537**
Sp. subochreatum (F.Muell.) Reissek	ANBG 636419c Nursery	*J. McAuliffe 250* (CANB)	silica; 2003	**EF528532**
Sp. thymifolium Reissek	ANBG 631015 Nursery	*J. Nightingale 139* (CANB)	silica; 2003	**EF528533**
Sp. ulicinum (Hook.) Benth.	Tas.: Fehlbergs Road	*A.M. Buchanan 15952* (MEL)	fresh; 2002	**EF528523**
Sp. waterhousei F.Muell.	ANBG 9700078	*I. Jackson 13* (CBG at CANB)	silica; 2003	**EF528538**
Sp. sp. 1 *sensu* N.G.Walsh *in* Fl. Victoria	RBG Melbourne	*J. Kellermann 113* (MEL)	fresh; 2000	**EF528525**
Stenanthemum argenteum A.R.Bean	Qld: Mt Mulligan	*J.R. Clarkson 8895* (CANB)	herb.; 1990	**EF528542**
St. centrale K.R.Thiele	NT: Palm Valley	*D.V. Matthews s.n.* (MEL)	silica; 2002	**EF528544**
St. complicatum (F.Muell) Rye	WA: Kalbarri N.P.	*J. Kellermann 239* (MEL)	fresh; 2001	**EF528539**
St. gracilipes Diels	WA: Northampton	*J. Kellermann 262* (MEL)	fresh; 2001	**EF528506**
St. grandiflorum (C.A.Gardner) Rye ms	WA: Peterwangi Hill	*J. Kellermann 274* (MEL)	fresh; 2001	**EF528504**
St. humile Benth.	WA: Hi Vallee Farm, Badgingarra	*J. Kellermann 194* (MEL)	silica; 2001	**EF528540**
St. leucophractum (Schldl.) Reissek	Vic.: Little Desert	*J. Kellermann 136* (MEL)	silica; 2001	**EF528545**
St. petraeum Rye	NT: Watarrka N. P.	*T.L. Collins s.n.* (MEL)	fresh; 2002	**EF528541**
St. pomaderroides (Reissek) Reissek	WA	Richardson et al. (2000a) (as *Spyridium* cf. *forrestianum* F.Muell.)		AJ251690
St. reissekii Rye	WA: Hi Vallee Farm, Badgingarra	*J. Kellermann 197* (MEL)	silica; 2001	**EF528543**
Trymalium angustifolium Reissek	WA: Talbot State Forest, York	*J. Kellermann 302* (MEL)	fresh; 2001	**EF528548**
T. elachophyllum Rye	WA: Hopetoun	*J. Kellermann 384* (MEL)	fresh; 2001	**EF528547**
T. floribundum Steud.	WA	Richardson et al. (2000a)		AJ390362
T. ledifolium var. *rosmarinifolium* (Steud.) Benth **1**	WA: Flynn State Forest, York	*J. Kellermann 294* (MEL)	fresh; 2001	**EF528551**
T. ledifolium Fenzl **2**	WA	Richardson et al. (2000a)		AJ390361
T. monospermum Rye	WA: Narrogin	*L.W. Sage 1540* (MEL)	herb.; 1999	**EF528546**
T. wayi F.Muell. & Tate	SA: E of Crystal Brook	*D.N. Kraehenbuehl 5197* (CBG at CANB)	herb.; 1989	**EF528509**

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Byblis guehoi (Byblidaceae), a new species from the Kimberley, Western Australia

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Abstract

A new species of carnivorous plant from the Kimberley region of Western Australia north east of Broome, ***Byblis guehoi*** Lowrie & Conran, is described and illustrated. SEM micrographs of the seed, and chromosome data are also provided. The species is compact, multi-branched, glandular-leaved, bearing numerous flowers, and anchored to the soil by a solitary root system. When compared with other *Byblis* species, the new taxon is unique, differing in its particular combination of branching, floral, seed sculpturing characters, as well as being tetraploid.

Introduction

In August 2004, an unusual compact, much-branching, glandular carnivorous plant bearing many flowers and anchored to the soil by a solitary root system was discovered by Russ Guého north east of Broome in the Kimberley region of Western Australia (Fig. 1). When compared with known taxa in Lowrie and Conran's (1998) revision of *Byblis* in northern Australia, plus seed and chromosome features for the genus (Conran et al. 2002a, Conran et al. 2002b) the new taxon was clearly unlike any previously described species (Table 1) and is here described as new.

Byblis guehoi Lowrie & Conran, ***sp. nov.***

Affinis *Byblide filifolia*. Herba decumbens, ramulosa, e radice unica oriens. Pedicelli foliis longiores. Corolla subroseo-malvina, abaxialiter albida. Semina favosa cristis longitudinalibus denticulatis.

Holotype: WESTERN AUSTRALIA: 300 metres north of Bobbys Creek, near Beagle Bay Mission, c. 137 road km NE of Broome, Dampier Peninsula, Kimberley, 16°57'39"S, 122°46'26"E, *A. Lowrie 3215* & *R. Guého*, 6 September 2004 (PERTH). Isotype: MEL.

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Table 1. Comparison of *Byblis geuhoi* and related taxa. *refers to erect terminal shoots or branches; actual stems much longer but then decumbent or floating.

Feature	***B. guehoi***	***B. aquatica***	***B. filifolia***	***B. liniflora***	***B. rorida***
Habitat	wet/dry	wetlands	wetlands	wetlands	wet/dry
Height (cm)	up to 10*	up to 5*	20–60	5–15	6–30
Branching	multiple, common	absent	few, rare	absent	few, rare
Sessile glands covering shoot apex	absent	absent	absent	absent	present
Pedicels longer than leaves	yes	no	no	yes	no
Sepal length cf petals	>half	<half	>half	>half	<half
Petal colour abaxially	white	purple	white to yellow or yellow and mauve-striped	white	white
Petal margins	dentate	rounded	rounded to denticulate	rounded to denticulate	dentate
Filament colour	purple	pale lavender	pale lavender	pale lavender	purple
Anther length cf filaments	longer	<half	longer	<half	<half
Seed size (mm)	0.7–0.8 x 0.5–0.6	0.9–1.3 x 0.4–.07	0.4–1.1x 0.3–0.8	0.5–0.9 x 0.4–0.6	0.5–0.8 x 0.4–0.6
Seed furrowing	absent	present	absent	absent	absent
Seed anticlinal sculpturing	denticulate	smooth	smooth to denticulate	denticulate	denticulate
Chromosome number (2n)	32	16	16	32	16

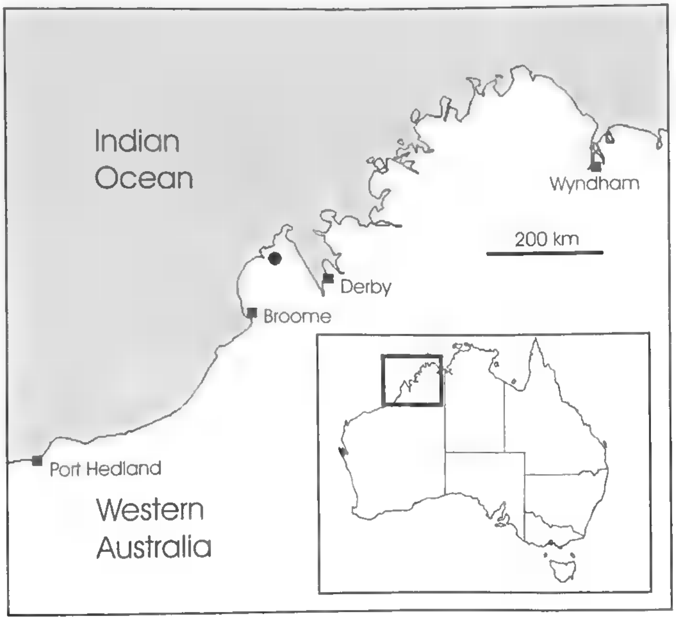

Fig. 1. Map showing the current single known locality for *Byblis guehoi*.

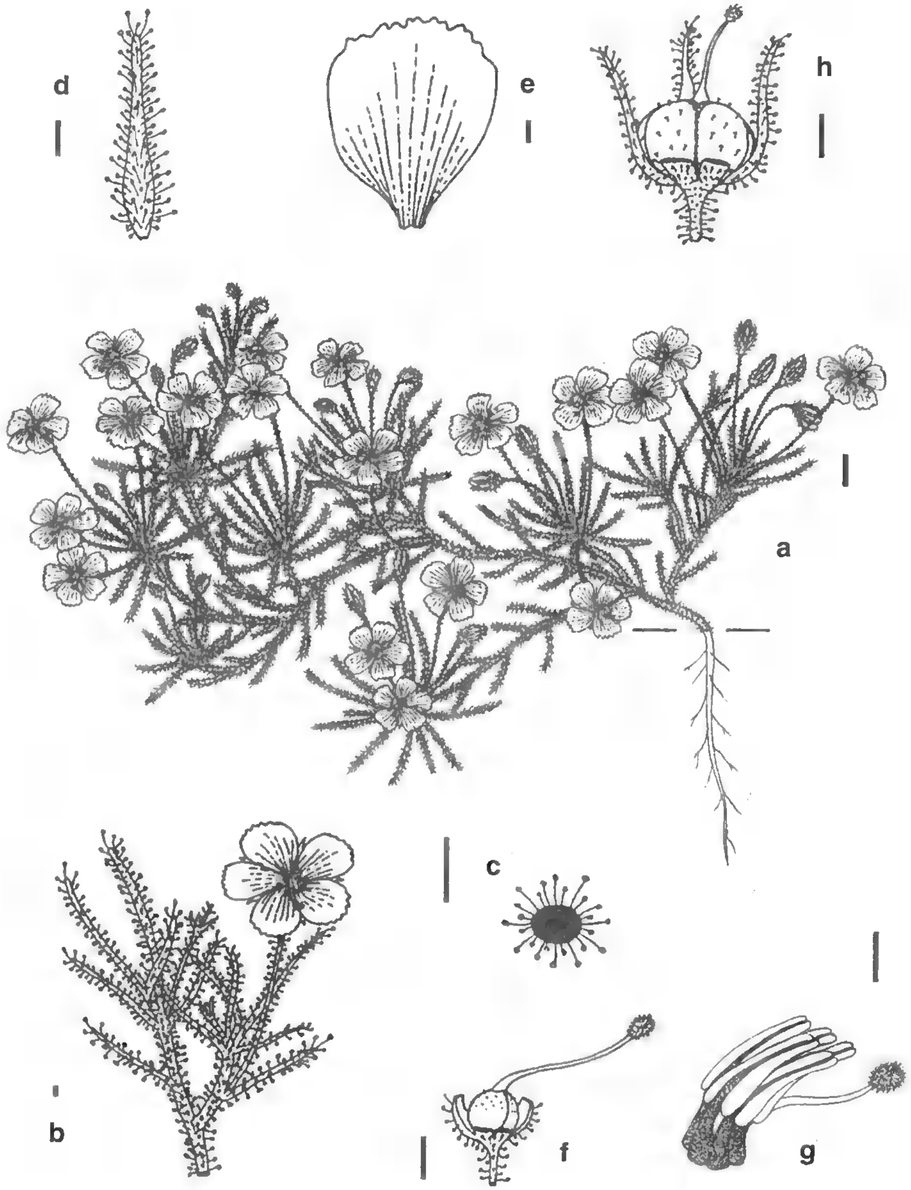

Fig. 2. *Byblis guehoi* **a,** plant; **b,** flowering shoot apex; **c,** leaf section; **d,** sepal; **e,** petal; **f,** ovary, filaments, anthers and style-stigma; **g,** filaments-anthers, enlarged; **h,** seed capsule. Scale bars for a = 10 mm, b–h = 1 mm. Drawn in 2006 by Allen Lowrie from live material collected from the type location; voucher *A. Lowrie 3215* & *R. Guého* (PERTH, MEL).

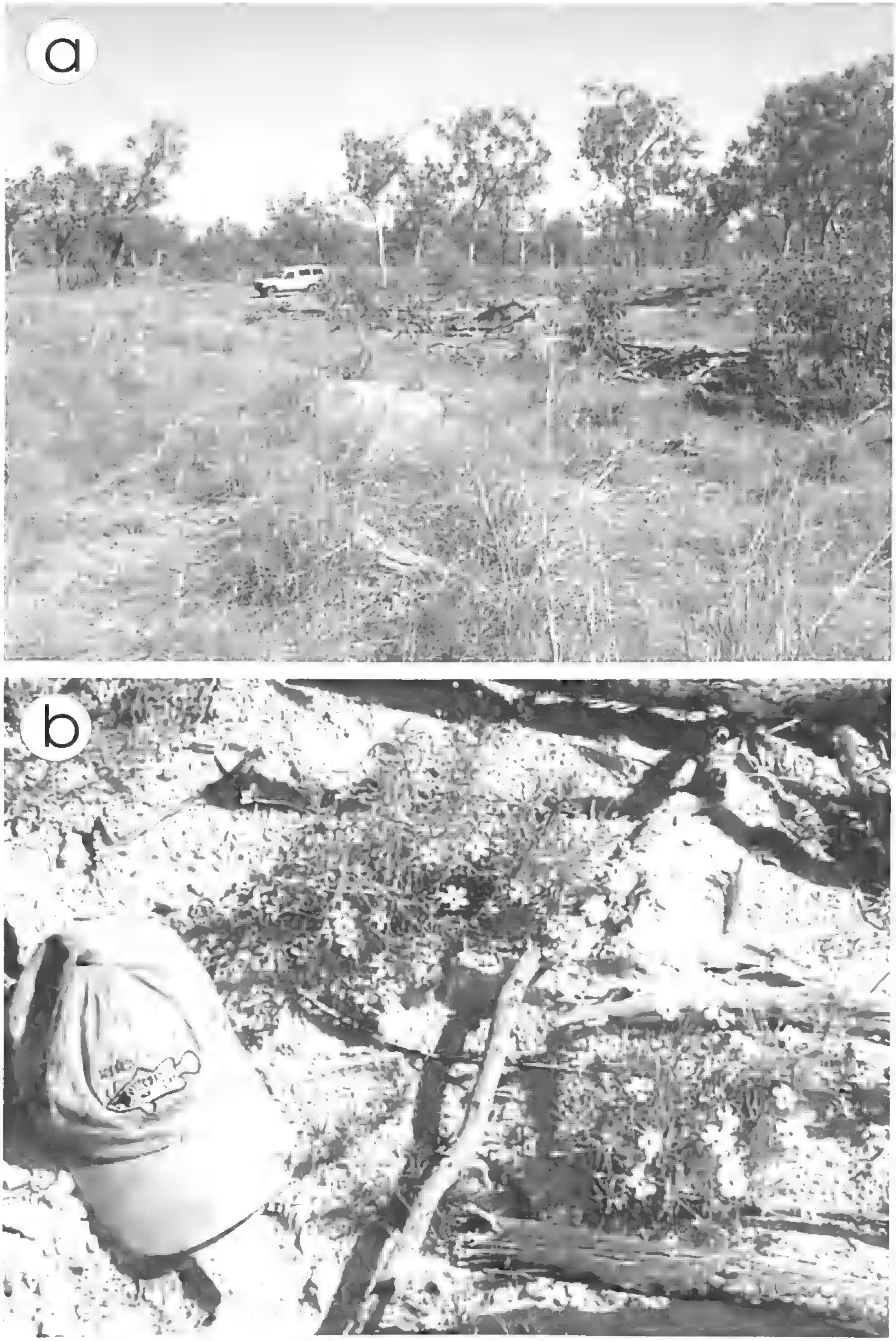

Fig. 3. Habitat at the type locality. **a,** *Acacia-Eucalyptus* open woodland with low tussock grasses and open sandy soil patches; **b,** *Byblis guehoi* growing on seasonally waterlogged but rapid-drying sandy loam.

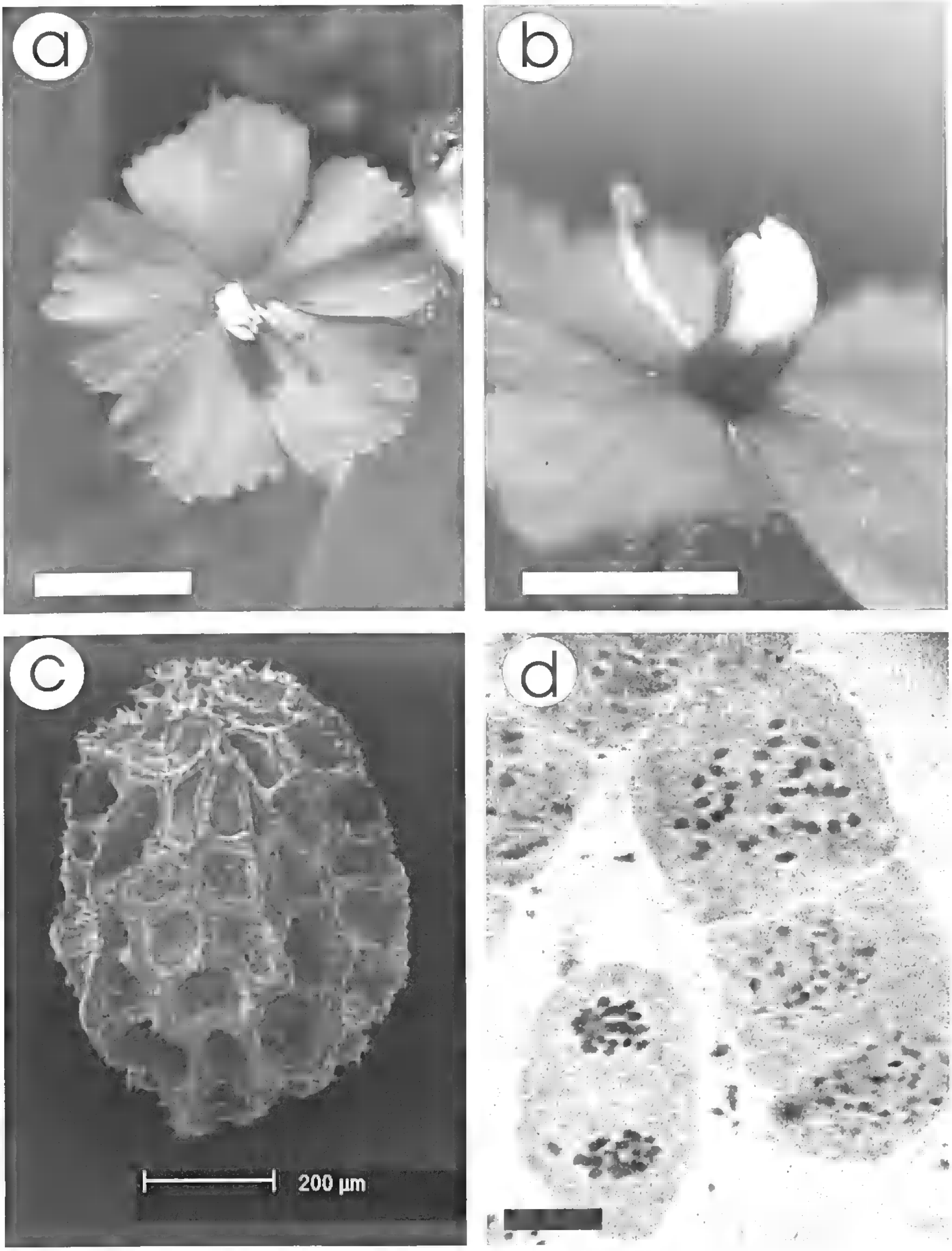

Fig. 4. *Byblis guehoi* **a,** flower ; **b,** stamen detail showing deep colouring (purple) on the filaments and abaxially on the anthers; **c,** seed; **d,** chromosomes. Scale bar for a = 10 mm, b = 5 mm, c as indicated, d = 10 µm. Material grown at ADU from seed from the type locality; voucher *A. Lowrie 3215* & *R. Guého* (PERTH, MEL).

Annual *herb* with one or more decumbent *major axes* 15–18 cm long, 2–3.5 mm diam., developing from a solitary root system, each terminating in an erect leafy many flowered head-like shoot, 6–8 cm tall, branching at random along their length and producing new major axis innovations terminating in a leafy flowering shoot; flowers under ideal moist growing conditions 15–20 mm diam., flowers produced as the dry season approaches much smaller, to one third this size; leafy apices of all leafy flowering shoots commonly producing a further compact 3 to 4 clusters of shorter stemmed leafy flowering shoots, together spreading to 20–30 cm diam.; overall colour appearing hazy (when viewed in full sunlight) because of the dense covering of translucent long and short glandular indumentum over the green- or bronze-coloured major axes, leaves and pedicels. *Leaves* filiform, shorter than the pedicels, 2.5–3.3 cm long, elliptic in section, c. 1 mm wide × c. 0.5 mm thick at the base tapering towards the apex; entire leaf length and circumference densely covered with long and short translucent glands. *Inflorescences* solitary, erect to semi-erect, arising from the axils of the leaves, pedicels longer than the leaves, 3.5–8 cm long, 1–1.5 mm diam. *Sepals* 5, green, lanceolate, apically ± acute, outer surface glandular, 4.5–6 mm long, 0.8–1 mm wide near the base. *Petals* 5, adaxial flower surface pinkish mauve, (R.H.S. colour chart[1], purple-violet 88 C) with faint darker mauve fan-like veining from the base, abaxial surfaces white, obovate, margins entire, except for the apex which is irregularly serrate and dentate, 9–12 mm long, 7–12 mm wide. *Stamens* 5, anthers longer than the supporting filaments, each longitudinally positioned close to each other, releasing pollen in unison, 4–6 mm long, filaments purple, clustered together, 1.5–2 mm long, anthers yellow with purple-brown longitudinal tapering supporting filament extension between, 3.5–4 mm long, pollen yellow. *Ovary* green, ± globose, 1–1.5 mm diam. *Style* pale mauve, solitary, decurved to place the style below the anther cluster, longer than the stamens, 4.5–5 mm long, apically dilated, stigma darker mauve. *Capsule* broadly obovoid, compressed a little across its width, 3–4 mm long, 4–5 mm wide, sparsely glandular. *Seeds* black, shiny, irregularly shaped, ± ovoid to elliptic in outline, 0.7–0.8 mm long, 0.5–0.6 mm diam., denticulate longitudinal ridges and shallow transverse ridges between, producing honeycomb-like sculpturing. (Figs 2–4).

Byblis guehoi (pronounced gay-ho-eye) is known currently only from the type location near Beagle Bay Mission, Kimberley, Western Australia (Fig. 1), but is locally abundant and not currently under threat. The vegetation consists of low native tussock grasses with open sandy soil patches between (Fig. 2a), bordered by scattered *Acacia tumida* F.Muell. ex Benth. (Mimosaceae) shrubs and trees, and taller *Eucalyptus tetrodonta* F.Muell., *E. miniata* A.Cunn. ex Schauer and *Corymbia bella* K.D.Hill & L.A.S.Johnson (Myrtaceae) woodland on the higher ground. The species is found in open ground on an Orthic Tenosol soil consisting of a mixture of beige sand (a mix of amber colour tones and glass-like granules) and loam silt (Fig. 2b). These soils generally show low water retention capacity, are very nutrient-poor (Isbell et al. 1997), and, at the type locality, *B. guehoi* grows in a part of the Bobbys Creek watershed that is waterlogged in the wet season, but completely dry soon after.

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[1] Royal Horticultural Society London. 1966. R.H.S. Colour Chart in association with the Flower Council of Holland. Published by The Royal Horticultural Society LONDON and Flower Council of Holland LEIDEN.

Honours Russ Guého, the biologist, author, wildlife photographer and teacher from Broome who first collected the new taxon.

Byblis guehoi is easily distinguished from all other *Byblis* species by its decumbent, multi-branching, head-like many-flowered habit. Its apically dentate petals are reminiscent of *B. rorida*, as is its more open, drier habitat, but it lacks the apical shoot glands and short sepals of that species (Fig. 3a). Anther length (Fig. 3b) places it with the *B. filifolia* complex but it differs in the seeds (Fig. 3c) and chromosome number (Fig. 3d). There are also features such as chromosome number and long pedicels which suggest affinities to *B. liniflora*, but phylogenetic relationships within the genus are currently unresolved and the subject of ongoing research.

Acknowledgments

Russ Guého is thanked for his significant help through his field collections and observations, data, personal comments and discussions since this species' discovery. DEC WA is thanked for permission to collect plant materials from lands under their control. Peter Wilson is thanked for assistance with the Latin diagnosis. The School of Earth and Environmental Sciences at The University of Adelaide is thanked for the provision of facilities to undertake part of the research.

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A new species and section of *Utricularia* (Lentibulariaceae) from northern Australia

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Abstract

A minute, reddish-purple-flowered, new species of *Utricularia* L. subgenus *Utricularia* (Lentibulariaceae) is described and illustrated: ***Utricularia simmonsii*** Lowrie, Cowie & Conran from the western Top End of the Northern Territory and near Lockhart River and Tozer's Gap, Iron Range in far north Queensland. The species represents possibly the world's smallest-flowered carnivorous plant. It shows some affinities to *Utricularia* sections *Enskide* and *Pleiochasia*, but possesses a combination of features not found in any other *Utricularia* species. The tiny flowers have an open, gullet throat, virtually lack a spur (both unusual features in the genus), the traps lack obvious trigger or guiding hairs, and the seeds have almost fingerprint-like swirled sculpturing. Because of its distinctness, it is placed into a new section: ***Minutae*** Lowrie, Cowie & Conran. A key to the *Utricularia* taxa found in Northern Australia is also provided.

Introduction

The genus *Utricularia* with over 220 species worldwide is well represented in Australia with Taylor (1989) listing 64 species, and two more described since then (Lowrie 1998a, b, 2002), bringing the current total to 66 species in 13 sections. There are also numerous undescribed taxa from the Australian tropics (R. Barrett, D. Dixon and J. Clarkson pers. comm.).

The monsoonal Top End of the Northern Territory (NT) has been identified as a world centre of diversity for the genus *Utricularia* L. (Lentibulariaceae) with 36 taxa known

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from the area (Taylor 1989). Indeed, the area supports a diverse assemblage of specialist plant species on seasonally waterlogged, infertile, sandy soils particularly associated with the lowlands of the Koolpinyah Surface of Williams (1969) as well as the Western Arnhem Land Plateau. Many of the taxa involved are endemic to the NT (Woinarski et al. 2006). The habitat is extensive and finely divided by subtle gradients in soil texture, drainage, period of inundation and water flow. This in turn influences the species composition across the landscape and appears to have allowed a rich flora to develop. During studies of the effects of sand mining on this habitat an undescribed species of *Utricularia* was seen in the field and collections were subsequently made over a number of years.

Similarly, in October 2005, the same minute-flowered new species of *Utricularia* was found growing with cultivated material of a much larger-flowered *Utricularia* species from Turtle Creek crossing, Iron Range. It was also found near the Lockhart River community refuse site; and along the Lockhart River near Tozer's Gap in far north Queensland (Fig. 1).

When compared against Taylor's (1989) monograph of *Utricularia*, these collections clearly represented a new taxon quite unlike any previously described species. Taylor records six tiny-flowered *Utricularia* in his monograph: *U. albiflora* R.Br. (fig. 28, p. 151), *U. quinquedentata* F. Muell. (fig. 29, p. 153) from Australia; *U. cymbantha* Oliver (fig. 208, p. 680) from Africa; *U. naviculata* P. Taylor (fig. 209, p. 682) from South America; *U. biovularioides* (Kuhlum.) P. Taylor (fig. 210, p. 684) from South America; and *U. olivacea* Wright ex Griseb. (fig. 211, p. 687) from the Americas. *U. quinquedentata* and the closely-related *U. albiflora* were previously regarded as the smallest in the genus, but the new species is shorter in stature and has a smaller corolla. When these other species are compared to the new taxon, the minute corolla size of the latter easily make it the world's consistently smallest-flowered *Utricularia* (and carnivorous plant) species so far discovered.

Accordingly, the new species is named here and its affinities to the remainder of the genus are discussed. A key to the 45 *Utricularia* species found in northern Qld, the NT and the Kimberley Region of WA is provided here to enable identification.

Methods

Morphological characters were examined at DNA and ADU using fresh, dried and spirit-preserved material, and seeds were examined under scanning electron microscopy.

The terminology used for *Utricularia* follows that generally accepted for the genus (Taylor 1989). Specifically, rhizoids in *Utricularia* resemble and function as roots; scales may be present on the peduncle (or inflorescence stalk); a bract can be found opposite or subtending each flower pedicel and often two bracteoles occur laterally to the bract.

Taxonomy

Utricularia simmonsii Lowrie, Cowie & Conran ***sp. nov.***

Herba minuta. Folia angustissima filiformia, rariora oblonga. Vesiculae nudae vel glandulis sessilibus dispersis; appendix dorsalis singula; saetae irretitantes papillatae.

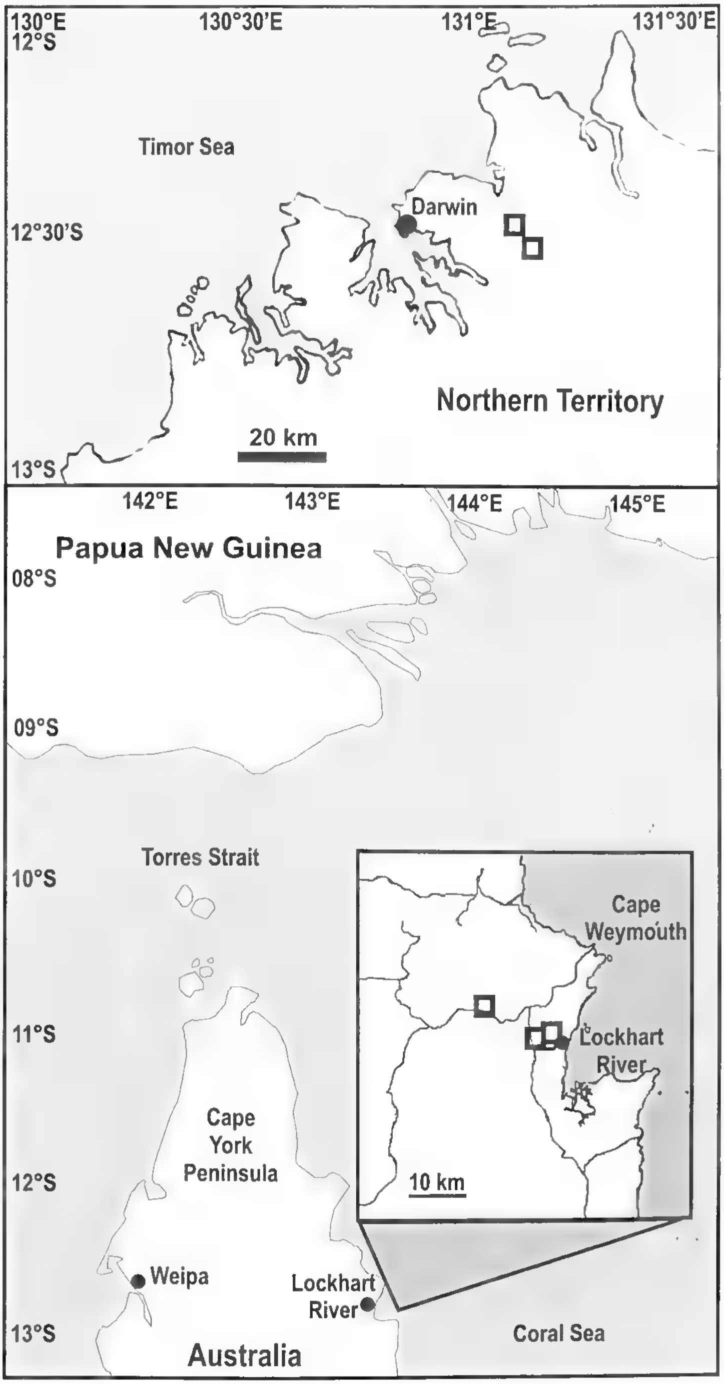

Fig. 1. Maps showing the current known distribution for *Utricularia simmonsii* in the Northern Territory and Queensland.

Flores 1–2(–3) minutissimi, purpureo-rubri. Corolla cucullata; calcar vel faux clausa deficiens; labium inferum integrum limbo diminuto. Stamina et stylus per corollam inclusus attamen conspicuus. Semina turbinata, mellea, testa longitudinaliter striata.

Holotype: Northern Territory: 1km north of Girraween Rd - Anglesey Rd corner, 12°30'S 131°06'E, *R.K. Harwood 1550*, 3 June 2006 (DNA). Isotypes: AD, BRI, CANB, K, MEL, MO, NSW, PERTH.

Small perennial or annual (some NT populations) *herb* forming colonies up to 1 m diameter and 3–8 mm tall above ground. *Rhizoids*, capillary, simple, to 8 mm long, tapering, 0.04–0.1 mm diam. *Stolons* reticulate, capillary, branched or not, c. 0.1 mm diam., internodes 1–3 mm long. *Leaves* solitary, 3.5–15 mm long in total, petiole indistinct, lamina linear, dimorphic, 1-nerved, mostly filiform, terete, apex acicular, rarely oblong and flattened, 0.3–0.4 mm wide, apex acute, sometimes rounded. *Traps* scattered on stolons and rhizoids with up to 6 on lower part of leaf margins, stipe 0.1–0.5 mm long, traps upwards-facing, dimidiate to ovate with a falcate apex, 0.2–0.5 mm long, 0.2–0.3 mm wide, glabrous or with scattered sessile glands; dorsal appendage short, obtuse, glabrous or papillate; lateral appendages and ventral wings absent; trap orifice hyaline or reddish-pink, threshold glands 1-armed, internal glands bifid, arms ellipsoid and ovoid *c.* 3 times as long as wide. *Inflorescence* erect, solitary, 1–2(rarely 3)-flowered, 6–17 mm long, peduncle terete, glabrous, 0.1–0.3 mm diam., green, red-purple ([1]72B) towards apex, scales absent, with or without raised longitudinal verrucae scattered over the surface which shine silver in sunlight, otherwise glabrous. *Bracts* and bracteoles basifixed, glabrous, red-purple; bracts broadly ovate-deltoid, 0.3–0.5 mm long, apex acute or ± 3-lobed; bracteoles 2, opposite, basifixed, lanceolate or subulate, c. 0.25 mm (Qld) or 0.4–0.5 mm long (NT), c. 0.2 mm wide, apex acute. *Flowers* 1–3. *Calyx* lobes 2, unequal, red-purple (72B); upper lobe ± orbicular, strongly concavo-convex, 0.75–1 mm long and apex truncate (NT) or elliptic, apically ± acute and involute (Qld); lower lobe broadly elliptic, concavo-convex, 0.5–0.75 mm long (NT) or 1–1.2 mm long (Qld), 0.7–0.8 mm wide, apex rounded or emarginate, revolute. *Corolla* red-purple (72B), paler at very base, two lipped, connate at base, 0.7–1.3 mm long; upper lip ovate-oblong, 0.7–1 mm long, apex rounded to retuse (NT) or involute (Qld); lower lip 0.8–1.3 mm long, broadly elliptic, entire, the limb reduced to a narrow reflexed margin c. 0.5 mm long, apex obtuse to rounded, glabrous, without a conspicuous rim, shorter than lower calyx lobe; palate absent (Qld) or conspicuous and red-purple (NT); *Spur* virtually absent. *Stamen* filaments 2, white, supporting white anthers visible within the corolla hood, anthers posterior to the stigma, pollen white, 5–6-colporate, obloid, c. 22 µm long. *Style* red, lingulate, anteriorly stigmatic. *Ovary*, ovoid, unilocular, c. 0.3 mm long, placenta basal, free, globular. *Capsule* globose-ovoid, 0.6–0.8 mm long, 0.6–0.75 mm diam., red-purple (72B) with a paler single ventral, longitudinal, elliptic pore, drying stramineous and enclosed in fruit by persistent calyx lobes, dehiscent (NT) or indehiscent (Qld). *Seeds* numerous, stramineous to honey-brown, broadly ellipsoid to obovoid, sub-angular, or turbinate, 0.125–0.175 mm long, cells elongate, longitudinally striate-swirled, resembling a fingerprint. (Figs 2–4)

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[1] Royal Horticultural Society London. 1966. R.H.S. Colour Chart in association with the Flower Council of Holland. Published by The Royal Horticultural Society LONDON and Flower Council of Holland LEIDEN.

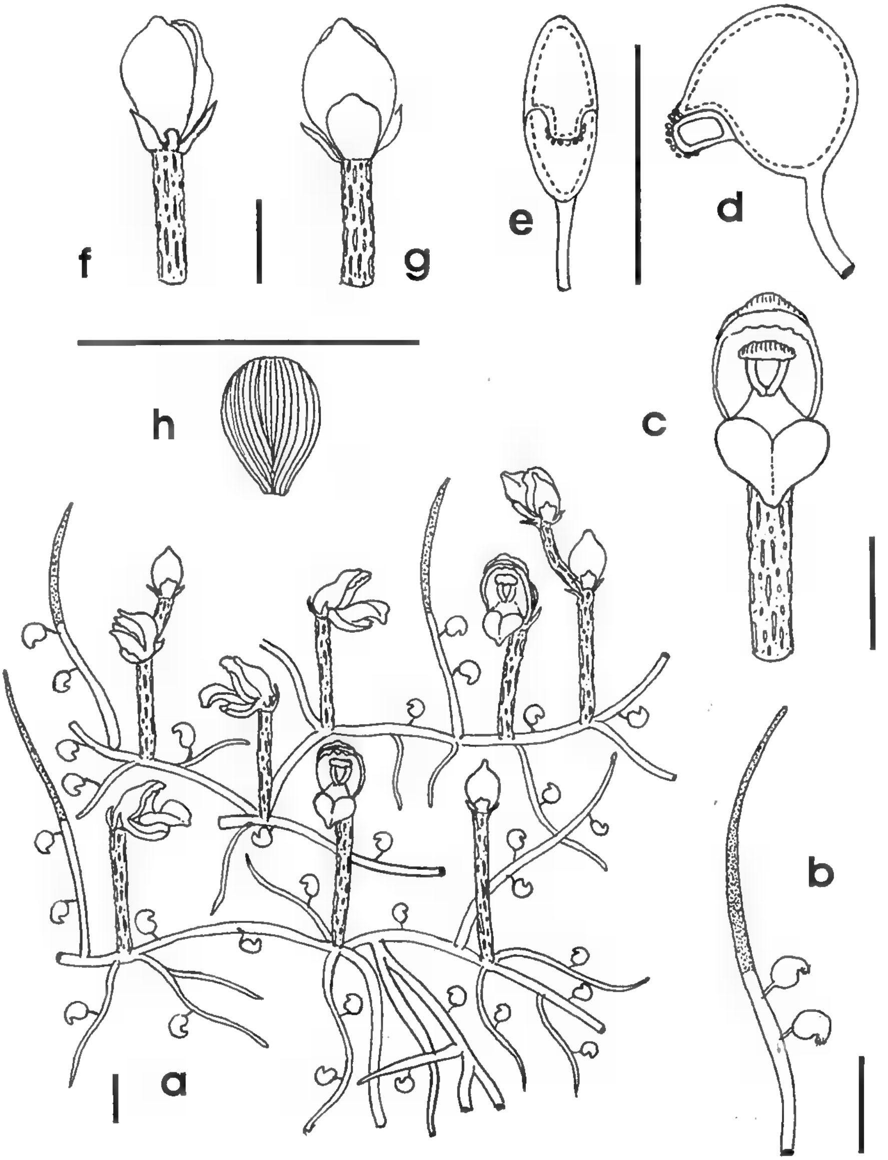

Fig. 2. *Utricularia simmonsii:* **a,** plant; **b,**leaf; **c,** corolla; **d,** side view of trap; **e,** front view of trap; **f,** bracteoles; **g,** bract; **h,** seed; Scale bars for d, e & h = 0.5 mm, all other scale bars = 1 mm. Drawn from live, cultivated material, ex Paul Simmons, from Lockhart River, far north Queensland by A. Lowrie 2005. Voucher *A. Lowrie 3159* & *P. Simmons* (BRI, PERTH, MEL. K).

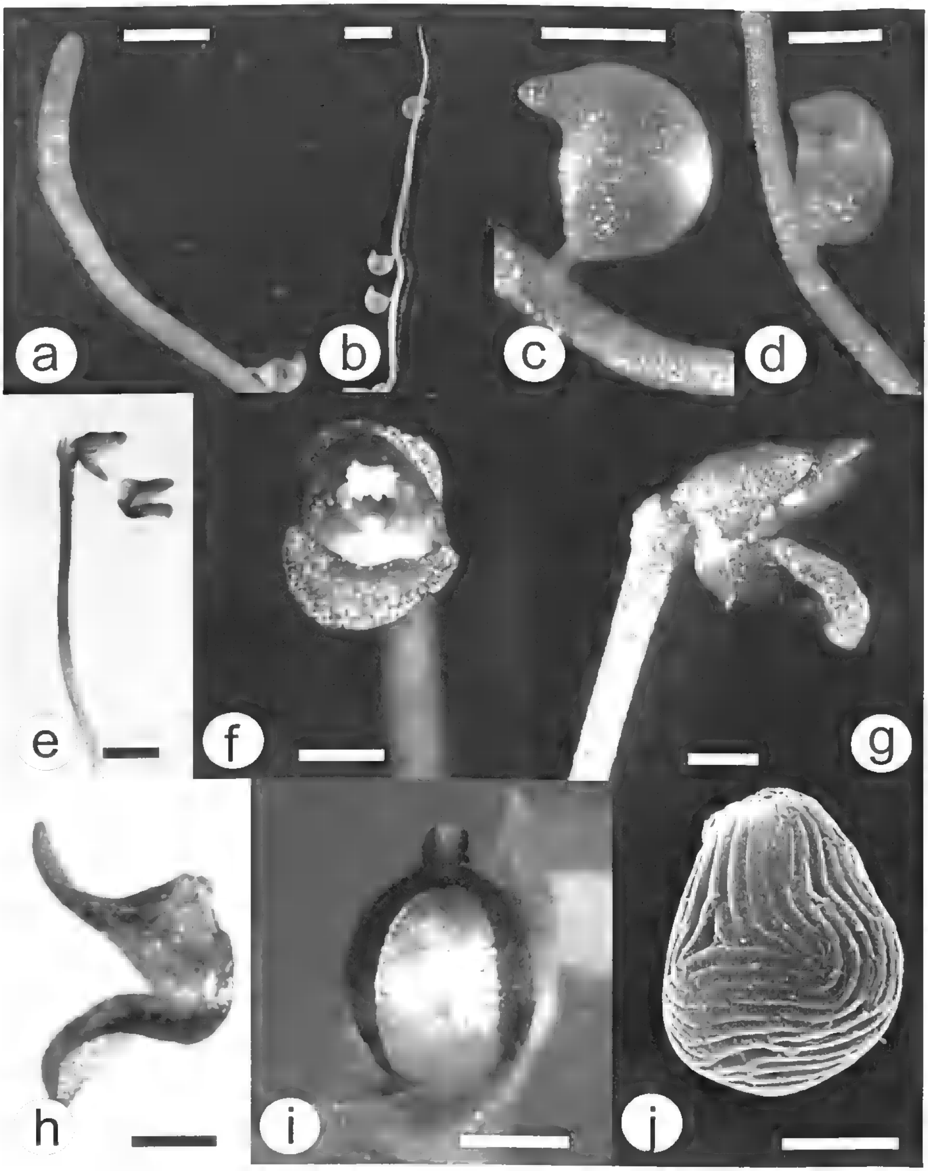

Fig. 3. *Utricularia simmonsii:* **a,** leaf and trap; **b,** leaf and traps; **c,** trap, lateral view; **d,** trap; **e,** flowering peduncle; **f,** flower; **g,** flower, lateral view; **h,** corolla, lateral view; **i,** nearly mature capsule (enclosing calyx removed) showing lateral longitudinal pore; **j,** seed. Scale bars for a, b & e = 1, c, d & i = 0.25 mm, f–h = 0.5 mm, j = 50 µm. Vouchers a–h, *Harwood 1550* (DNA); i–j, *A. Lowrie 3159* & *P. Simmons* (BRI, PERTH, MEL. K).

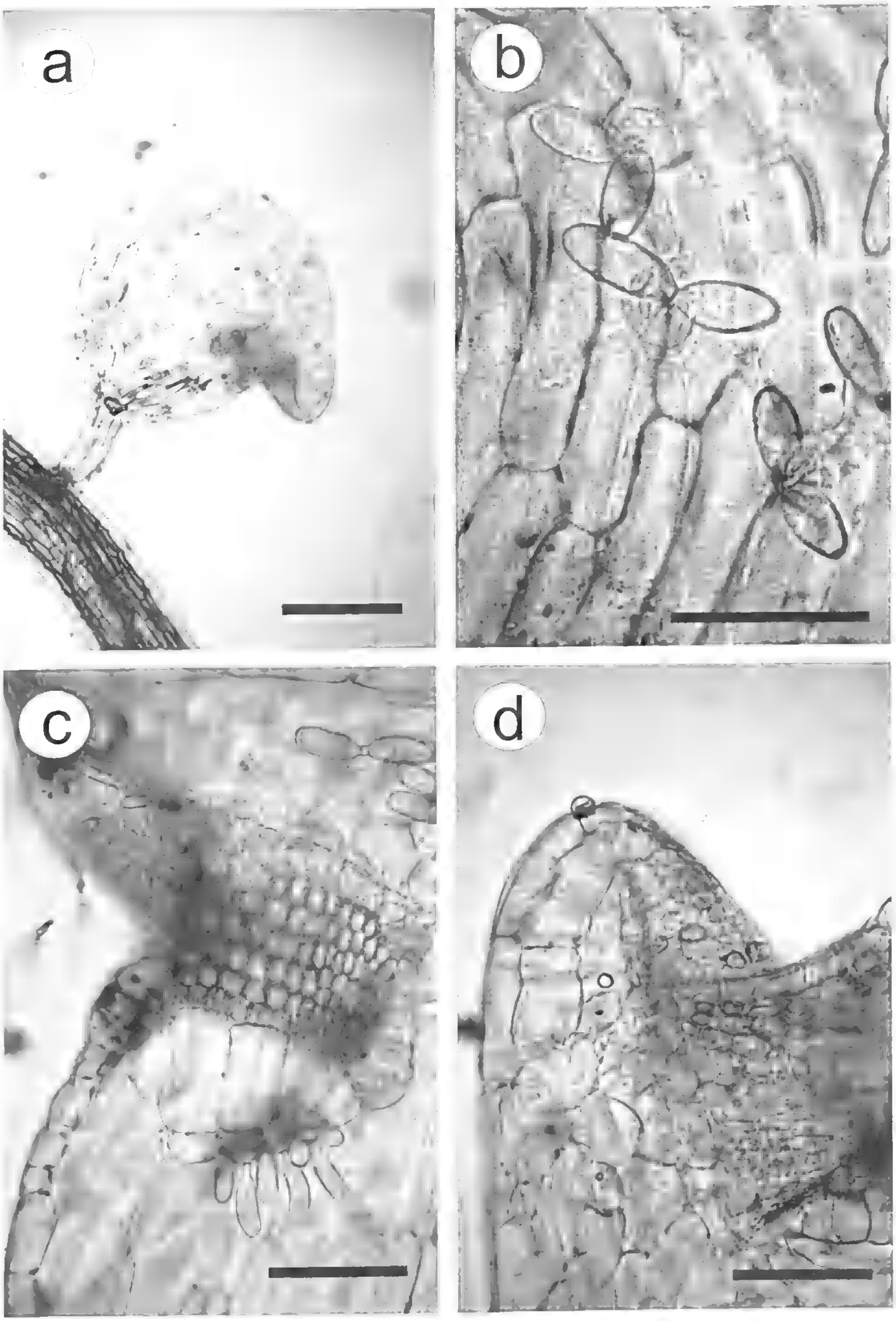

Fig. 4. *Utricularia simmonsii:* **a,** trap; **b,** trap internal bifid glands; **c,** trap orifice and 1-armed threshold glands ; **d,** dorsal process of trap showing external glandular trichomes. All to indicated scales. Photographed from live, cultivated material, ex Paul Simmons, from Lockhart River, far north Queensland. Scale bar for a = 100 µm, b–d = 20 µm. Voucher *A. Lowrie 3159* & *P. Simmons* (BRI, PERTH, MEL. K).

Other specimens examined: Northern Territory: Howard River Hunting Reserve, 12° 26'S, 131°04'E, 7 Jul 1995, *J.L. Egan* 5133 & *I.D. Cowie* (DNA); 1 km. N of Girraween Rd., 1 km. W of Howard River, 12°30'S, 131°06'E, 17 May 1996, *R.K. Harwood* 145 (DNA); 1km north of Girraween Rd - Anglesey Rd corner, 12°30'S 131°06'E, 3 May 2001, *R.K. Harwood* 1084 (DNA); 1km north of Girraween Rd - Anglesey Rd corner, 12°30'S 131°06'E, 7 May 2002, *I.D. Cowie* 10646 (DNA); 1km north of Girraween Rd - Anglesey Rd corner, 12°30'S 131°06'E, 16 Jun 2006, *R.K. Harwood* 1564 (DNA). **Queensland:** Turtle Creek crossing, Iron Range, c. 7.25 km NW of Lockhart River township, north Queensland, 12°46'S, 143°17'E, *A. Lowrie 3159* & *P. Simmons*, 28 Oct 2005 (BRI, PERTH, MEL, K); Tozer's Flat, Pascoe River, c. 17.7 km NW of Lockhart River township, north Queensland, 12°43'S, 143°12'E, *A. Lowrie 3213* & *P. Simmons*, 28 Oct 2005 (BRI, PERTH, MEL, K); Iron Range, near Lockhart River community refuse site, c. 1.2 km NW of Lockhart River township, north Queensland, 12°47'S, 143°20'E, *A. Lowrie 3214* & *P. Simmons*, 28 Oct 2005 (BRI, PERTH, MEL, K).

Distribution and ecology: the species occurs in the NW Northern Territory and on Cape York Peninsula, Queensland (Fig 1). In the Northern Territory it is known from only two localities on sand sheets associated with the Howard River floodplain in the Darwin rural area, where it grows in short herbland with *Bergia pusilla* Benth. (Elatinaceae), *Centrolepis exserta* (R.Br.) Roem. & Schult. (Centrolepidaceae), *Eriocaulon cinereum* R.Br. (Eriocaulaceae), *Trithuria lanterna* D.A.Cooke (Hydatellaceae) and *Utricularia chrysantha* R.Br., on almost pure sand just above the receding water line. These populations occur in seasonally inundated depressions formed in abandoned sand extraction excavations, on the upper margin of a non-estuarine floodplain. The species appears to flower later and perhaps occurs in a seasonally more deeply inundated habitat than many other attached NT *Utricularia* species.

Utricularia simmonsii is also known from three locations near the town of Lockhart River (12°47'S 143°21'E), Iron Range on Cape York. There, the species grows in a mixture of fine sand and grey silt on seasonally dry flatlands that are variably waterlogged or covered by very shallow water in the wet season. The areas are drained by shallow seasonal creeks, watersheds, drainage ditches, and rivulets running throughout the topography. The vegetation consists mainly of low growing herbs including many other *Utricularia* species, *Byblis liniflora* Salisb. (Byblidaceae), *Drosera petiolaris* R.Br. ex DC. (Droseraceae), *Lindernia* All. (Linderniaceae) and *Mitrasacme* Labill. (Loganiaceae) species. Scattered low shrubs also occur, as well as abundant orchids and *Nepenthes mirabilis* (Lour.) Druce (Nepenthaceae).

Phenology: flowering and fruiting are recorded from May to July.

Notes: comparison of specimens from the two regions where they occur reveals that although they are very similar, there are a number of leaf, trap, inflorescence, floral and fruit differences between them (Table 1). This possibly reflects the considerable distance between the populations (although this may in part also reflect under-collection due to the cryptic nature of the species). In particular, the bright pink area associated with the trap mouth (Figs 4c,d) seen in the Qld populations is unusual, or at least not a previously reported feature in the genus, and may serve as a visual attractant to potential prey. Similarly, the fruits in the Qld plants are tardily if at all dehiscent, apparently releasing the seeds only once the fruits have rotted. Nevertheless, given the small number of populations sampled and the need for more collections in the Northern Territory and Gulf of Carpentaria region of Queensland, these morphs are presently being regarded as conspecific pending more information.

Table 1. Comparison of features differing between the two regions where the new species occurs

Feature	Northern Territory	Queensland
Traps: position	mainly on leaf bases, up to six per leaf	mainly on rhizome and rhizoids, up to two on leaf bases
Traps: dorsal appendage	glabrous	papillate on margin
Traps: orifice	hyaline	red
Peduncle	without verrucae	with light-catching, hyaline verrucae
Bracts	ovate-deltoid, acute to shortly acuminate	obovate, apically ± 3-lobed
Calyx lower lobe	0.5–0.75 mm long; 1/2 as long as lower corolla lobe or less	1–1.2 mm long; more than 1/2 as long as lower corolla lobe
Corolla upper lobe	apical margin rounded to retuse	apical margin involute
Palate	obvious, red-purple	absent or virtually so
Capsule and basal pore	dehiscent	indehiscent

Utricularia simmonsii is separated from other *Utricularia* spp. by its diminutive stature, peduncle lacking scales, 1–2(rarely 3)-flowered inflorescence, small, red-purple hood-like flowers without a spur. Other features that characterise the species are the dimidiate, unadorned traps, obloid, 5–6-colporate pollen and a globular placenta attached at its geometric centre.

The species belongs in *Utricularia* subgenus *Utricularia* and shares some features with members of both section *Enskide* and section *Pleiochasia* but fits neither section well. The lack of scales on the peduncle, solitary or paired flowers, and the capsule dehiscing by an elliptic pore (albeit functionally indehiscent in the Queensland plants) suggest affinities to section *Pleiochasia*. This section is distributed across Australia, New Zealand and New Caledonia and includes 25 northern Australian species among them *U. capilliflora* F.Muell., *U. hamiltonii* F.E.Lloyd, *U. holtzei* F.Muell., and *U. rhododactylos* P.Taylor. However, the unadorned traps with a lateral orifice, the obloid, 5–6-colporate pollen and the globular placenta attached at its geometric centre suggest they it is also allied with section *Enskide*, which comprises the two northern taxa *Utricularia chrysantha* and *U. fulva*

Nevertheless, *U. simmonsii* is distinctive by possessing an open, hood-like corolla which clearly displays the anthers and stigma. The unique floral structure, especially the lack of a spur and the open-throated corolla makes it different not only from most other *Utricularia* species, but Lentibulariaceae in general, which are characterised in part by a basally spurred or saccate lower lip. This, combined with other unique shared features such as seed morphology, glandular hair types and position, and trap anatomy which are discussed below in more detail, justifies the erection of a new section to accommodate the species.

Etymology: the species is named in honour of Paul Simmons, schoolteacher, botanist, carnivorous plant and ant-plant enthusiast, who discovered the species in Queensland.

Conservation status: in the Northern Territory, the species is known from just two locations near Darwin. Although plants were locally abundant with hundreds of flowering stems per square metre, little is known of the true size and extent of populations. Plants are very cryptic and not easy to see by casual observation, even when flowering. In addition, as discussed further below, it is likely that survey effort directed at other *Utricularia* species is mistimed for detection of this taxon.

The possible threat posed to this species by sand mining is unclear. Curiously, the species is only known from abandoned sand mining scrapes at two localities. Generally, the poorly drained sandy soils in the Darwin area continue to be heavily exploited as a source of fine sand for building and construction (Doyle 2001) and the long term conservation status of the flora they support is of some concern. Field observation suggests that in some areas, sand mining has altered the local drainage to favour species that prefer deeper water and a longer period of inundation. On the available evidence, there is some indication that sand mining can favour this species by providing areas of sandy substrate that stay wet for longer into the dry season. On the other hand, no other populations have been found despite extensive survey work targeted at *Utricularia* species in similar habitat in the Darwin area, including a number of mined areas. However, given the apparent later fertile period of *U. simmonsii* (May-early July) there is some doubt as to whether the timing of this survey effort was appropriate to detection of this species. In addition, areas of similar habitat extend to the east of Darwin to as far as Cobourg Peninsula and Maningrida, including Kakadu National Park. These areas have not been intensively surveyed at an appropriate scale or time of year. Experience with other apparently restricted taxa suggests that the species is very likely to be found elsewhere when suitable habitat is surveyed using an appropriate methodology.

The known populations occur on vacant free hold land which is proposed to become part of a bore field for the extraction of potable ground water for the City of Darwin and on the Howard River Hunting Reserve. In the short term, it appears it is at least offered some protection from clearing for residential or horticultural development, although the likely impacts of any adjacent development on site drainage and water quality are unknown. It is not anticipated that increased extraction of ground water will affect the species, as it is likely more influenced by the seasonal abundance of surface water. The Howard River Hunting Reserve has a history of surface mining for the extraction of sand, but it is not known if further mining is planned. The area is also used for waterfowl hunting in season, and for recreational 4wd driving.

In far north Queensland, *Utricularia simmonsii* is considered locally abundant at its three known locations and currently not under threat. The Tozer's Flat locality is presently protected from development and/or mining as it is situated c. 4 km to the N of Mt Tozer and c. 2.5 km to the W of North Pap and South Pap, well within the boundaries of the Iron Range National Park

Nevertheless, using IUCN (2001) Red list categories and guidelines, this species cannot be considered adequately surveyed and a conservation code of Data Deficient is thus recommended. However, given the uncertainty regarding the impact of further development of the rural area on the only known NT populations of this species, it requires interim protection until further survey is conducted and the species can be reassessed against IUCN criteria.

Utricularia **section** ***Minutae*** Lowrie, Cowie & Conran, ***sect. nov.***

Herbae minutae. Vesiculae nudae vel glandulis sessilibus dispersis; appendix dorsalis singula; saetae irretitantes papillatae. Corolla cucullata; calcar deficiens; labium inferum integrum limbo diminuto. Stamina et stylus per corollam inclusus attamen conspicuus. Pollinia obloidea, 5–6-colporata. Ovarium placenta globulari in centro geometrico affixa. Capsula poro ventrali longitudinali instructa. Semina testa longitudinaliter torquato-striata.

Minute herbs. Bladders naked or with scattered sessile glands; with a single dorsal appendage; trapping hairs papillate; threshold glands 1-armed, internal glands bifid, arms ellipsoid and ovoid, c. 3 times as long as wide. Corolla hooded, lacking a nectary spur or a closed throat; lower lip lacking lateral lobes or an expanded pollinator landing apron. Stamens and style fully enclosed by corolla, but clearly visible. Pollen obloid, 5–6-colporate. Placenta globular, attached at its geometric centre. Capsule with a ventral longitudinal pore. Seeds with elongated cells, appearing longitudinally swirled and striated.

Type species. *U. simmonsii* Lowrie, Cowie & Conran

The relationships of the section are uncertain, although it bears some similarities in trap structure to the native sect. *Enskide*, as well as to the mainly South American sects. *Benjaminia*, *Stomoisia* and *Stylotheca* in lacking lateral appendages or ventral wings, and in the presence of papillae (Fig. 4d). In addition, although the sampled members of *Benjaminia* and *Stomoisia* were part of the same broader clade in molecular analyses (Jobson & Albert 2002, Jobson et al. 2003, Müller et al. 2004, Müller & Borsch 2005), they did not form a monophyletic lineage. This makes naked bladders with a slight dorsal bulge (Figs 2d, 3c–d, 4a) a paraphyletic character (Jobson & Albert 2002), and thus not necessarily grounds for placing *U. simmonsii* within, or relating it closely to any existing section.

The extreme reduction of the spur is uncommon in the genus. This character is shared only by the African *U. rigida* Benj. and *U. tetraloba* P. Taylor. In these species, the spur region is shallowly saccate whereas in *U. simmonsi* the spur is virtually absent.

Seed and internal trap gland characters are taxonomically important in the genus (Thor 1988, Taylor 1989) and there are also some similarities in seed sculpturing to the above groups, although the fingerprint-like pattern in sect. *Minutae* differs from all of the others (Figs 2h, 3j). Similarly, the internal trap glands most closely resemble the pattern seen in sect. *Stomoisia*, with ovoid 1-armed threshold cells (Fig. 4c) and the remainder bifid (Fig. 4b). Nevertheless, there are again too many floral and other differences between sects *Minutae* and *Stomoisia* to warrant its inclusion in the latter.

The presence and location of stipitate glandular hairs can be taxonomically important (Taylor 1989), although the significance of the structures is little understood. In *U. simmonsii* there are scattered sessile glands on the outside of the traps (Fig. 4d). The peduncle is ± glabrous, with raised longitudinal verrucae scattered over the surface which shine silver in sunlight.

Pollen morphology is generally consistent within sections in *Utricularia* and regarded as having considerable taxonomic importance (Taylor 1989). sect. *Minutae* has 5–6-colporate pollen, similar to sect. *Enskinde* (4–7 colporate), whereas sect. *Pleiochasia* has species with 3–4-colporate grains. Nevertheless, lower aperture numbers (3–8) are characteristic of the less derived members of the genus and occur in at least 11 sections making up the basal clades U1–4 of Jobson et al. (2003), suggesting that the feature is plesiomorphic and not strongly indicative of affinity.

Fruit dehiscence is another taxonomically important characteristic in Lentibulariaceae with 17 different patterns recognised, many of which have diagnostic potential at the sectional level (Taylor 1989). sect. *Minutae* has fruits with a single, ventral longitudinal elliptic pore (Taylor's Type E), but although the sutures are prominent in near-mature fruits, once the fruit dries they effectively disappear and the fruits remain enclosed by the persistent sepals and are indehiscent (at least in the Qld populations). Taylor noted that Type E fruits were almost universal in sect. *Pleiochasia*, but also found that they were the most common type, occurring in a wide range of *Utricularia* species. Nevertheless, this feature is apparently plesiomorphic within the genus (Jobson et al. 2003), making it of limited phylogenetic value. Similarly, sutureless fruits are known in some members of sects. *Pleiochasia* and *Utricularia*, and as Taylor (1989) observed, even some species with apparent suture lines may be functionally indehiscent. In contrast, species in sect. *Enskinde* dehisce by a single ventral pandurate pore, a unique feature in the genus which differentiates them from sect. *Minutae*, despite their trap and pollen similarities.

Overall, sect. *Minutae* seems to be closer on morphology to members of subgen. *Bivalvia sensu* Müller and Borsch (2005), although this requires molecular analysis to confirm, as well as wider comparisons with other taxa, especially the under-sampled northern Australian members of the family. Nevertheless, because sect. *Minutae* shows intermediacy in characters between several different sections in the genus, its precise affinities are uncertain, pending the results of ongoing morphological and molecular studies.

Key to the *Utricularia* species in tropical Australia

The key is derived from Taylor (1989) and the species are numbered according to his treatment to allow reference to descriptions there. Except where indicated, taxa occur in all regions (Western Australia, Northern Territory and Queensland). Species endemic to a particular state are indicated by an 'e' after the state abbreviation.

1 Plants free-floating or suspended in water; leaves usually much divided; bracteoles usually absent 2

1* Plants attached to substrate; leaves entire or 1–2(3)-divided; bracteoles usually present 7

2 Inflorescence stem with a whorl of ellipsoid floats above middle 3

2* Inflorescence stem without a whorl of floats or with narrowly fusiform floats at, or near the base 4

3 Floats shortly stipitate; calyx smaller than the capsule; seeds lenticular...... **193 *U. muelleri***

3* Floats sessile; calyx larger than capsule; seeds prismatic, winged .... **192 *U. stellaris***

4 Corolla pink; spur long and slender; bracts ovate .... **23 *U. tubulata***

4* Corolla yellow; spur conical to narrowly conical; bracts broadly ovate to orbicular 5

5 Ultimate leaf segments 2–8; upper corolla lip larger than lower .... **179 *U. gibba***

5* Ultimate leaf segments 20–80; upper corolla lip smaller than lower 6

6 Primary leaf divisions more than 2; scales absent; corolla pubescent outside .... **190 *U. aurea***

6* Primary leaf divisions 2; scales present on peduncle; corolla glabrous outside .... **184 *U. australis***

7 Peduncle twining **8**

7* Peduncle erect, not twining **10**

8 Corolla pale mauve, 3–4 mm long (NT, Qld) .... **115 *U. foveolata***

8* Corolla yellow, c. 5–15 mm long **9**

9 Corolla about 5 mm long, pale yellow (NT) .... **108 *U. circumvoluta***

9* Corolla 10–15 mm long, bright yellow (NT) .... **84 *U. involvens***

10 Corolla with 2 vertical filiform lobes **11**

10* Corolla lacking 2 vertical filiform lobes **14**

11 Capillary lobes arising laterally from the corolla lower lip base; flowers solitary **12**

11* Capillary lobes arising from the corolla upper lip apex; flowers 1 or 3–5 .... **13**

12 Corolla lower lip reduced to 3 minute teeth; apex of spur rounded (WA e) .... **36 *U. antennifera***

12* Corolla lower lip a well developed triangular lobe 1/3 or more times length of spur, lateral lobes minute or absent; spur apex emarginate (WA, NT) .... **35 *U. dunstaniae***

13 Corolla lower lip 5-lobed; flowers solitary (NT e) .... **33 *U. capilliflora***

13* Corolla lower lip 3-lobed; inflorescence 2–5-flowered (WA, NT) .... **34 *U. dunlopii***

14 Scales present on peduncle **15**

14* Scales absent **26**

15 Scales and bracts basifixed, bracteoles present **16**

15* Scales and bracts medifixed (or nearly so), bracteoles present or absent **22**

16 Corolla white or mauve **17**

16* Corolla yellow **19**

17 Corolla lower lip shallowly 3-lobed .... **37 *U. minutissima***[#]

17* Corolla lower lip entire, rounded or retuse **18**

18 Bracts more or less equal in width to bracteoles; spur conical, apex shortly and acutely bidentate (Qld, southern Aust.) .... **40 *U. lateriflora***

18* Bracts much wider than bracteoles; spur narrowly conical, apex acute .... **92 *U. uliginosa***

19 Corolla spotted with dark red; upper lip with 2 broad lobes (NT e) .... **81 *U. fulva***

19* Corolla unspotted, but nerves may be red or brown; upper lip entire or emarginate **20**

20 Corolla lower lip 4-lobed; bracts cordate at base .... **80 *U. chrysantha***

20* Corolla lower lip entire or shallowly 2-lobed; bracts not cordate **21**

21 Corolla 6–10 mm long, upper lip narrower than the calyx; inflorescence 3–30 cm tall .... **82 *U. bifida***

21* Corolla 10–15 mm long, upper lip wider than the calyx; inflorescence 25–55 cm tall (NT) .... **83 *U. odorata***

22 Corolla pale yellow; scales often ciliolate (NT) .... **165 *U. subulata***

22* Corolla white or blue to purple; scales glabrous **23**

23 Bracteoles present; corolla lower lip entire or obscurely lobed; leaves entire .... **43 *U. caerulea***

23* Bracteoles absent; corolla lower lip with 2 well developed lobes; leaves divided **24**

24 Corolla 10–25 mm long, spur 7–15 mm long; bracts 3–4 mm long (WA, NT) .... **174 *U. leptoplectra***

24* Corolla 4–10 mm long; spur 3–10 mm long; bracts 2.5 mm long or less **25**

25 Corolla dark blue-violet, 7–10 mm long; spur about as long as lower lip; leaf segments opposite (southern Qld) .... **175 *U. biloba***

25* Corolla white or pale, 3–6 mm long; spur longer than lower lip; leaf segments alternate .... **173 *U. limosa***

26 Corolla lower lip 5-lobed **27**

26* Corolla lower lip entire, crenate or 2–4-lobed **30**

27 Corolla white **28**

27* Corolla pink or mauve **29**

28 Corolla 4–8 mm wide (NT e) .... **30 *U. holtzei***

28* Corolla about 2 mm wide .... **29 *U. quinquedentata***

29 Corolla upper lip shorter than the upper calyx lobe; base of lower lip without ridges (NT e) .... **32 *U. cheiranthos***

29* Corolla upper lip longer than the upper calyx lobe; base of lower lip with 4 rounded ridges (NT e) .... **31 *U. rhododactylos***

30 Corolla 4 mm long or less **31**

30* Corolla 6 mm long or more **32**

31 Corolla c. 3 mm long, white to yellow, spur well developed and slightly longer than lower lip (Qld e) .... **28 *U. albiflora***

31* Corolla 1.5 mm long or less, dark pink to red, spur greatly reduced, apparently absent (NT, Qld) .... ***U. simmonsii***

32 Bracts and bracteoles medifixed (or nearly so), connate below the point of attachment and forming a tube around peduncle **33**

32* Bracts and bracteoles medifixed or basifixed, when medifixed, free below the point of attachment and not forming a tube around peduncle **34**

33 Corolla lower lip with 3 equal, narrow oblong-obovate lobes, white to pale mauve (WA e) .... **16 *U. georgei***

33* Corolla lower lip entire or obscurely 3-crenate, mauve (WA, NT) .... **15 *U. kimberleyensis***

34 Peduncle hairy, at least at base **35**

34* Peduncle glabrous, at most minutely papillose at base **38**

35 Bracts and bracteoles ciliate; bracts basifixed .... **24 *U. lasiocaulis***

35* Bracts and bracteoles not ciliate; bracts basifixed or medifixed **36**

36 Corolla pale mauve, lower lip of 3 long oblong lobes; bracts medifixed (NT e) .... **25 *U. kamienskii***

36* Corolla mauve to purple, lower lip of 3 short rounded lobes; bracts basifixed or medifixed **37**

37 Flowers usually solitary; upper lip constricted near base, upper part elliptic, apex emarginate (WA e) .... **26 *U. kenneallyi***

37* Flowers 2–4, rarely 1; upper lip constricted in centre, upper part oblong, apex more or less deeply bifid (WA, NT) .... **27 *U. leptorhyncha***

38 Corolla lower lip distinctly 3-lobed **39**

38* Corolla lower lip entire or obscurely 2–4-lobed **40**

39 Lobes of lower lip as long as wide (WA‡, NT) .... **19 *U. arnhemica***

39* Lobes of lower lip 3 times longer than wide (WA e) .... **20 *U. tridactyla***

40 Corolla spur not widely divergent from lower lip, erect, broadly obloid at base tapering to a dorsally flattened, narrow apex (WA[†], NT) .... **21 *U. singeriana***

40* Corolla spur diverging widely from lower lip, usually deflexed and narrow, apex acute to obtuse **41**

41 Spur broadly conical, obtuse, distinctly longer than lower lip; flowers 1(–3) (WA, NT[^]) .... **22 *U. fistulosa***

41* Spur narrowly conical, cylindrical or cylindrical-subulate, straight or tapering gradually, equal to or shorter than lower lip; flowers 1–9 .... **42**

42 Flowers 2–9, rarely 1; bracts often with the base more or less swollen, sometimes free .. **43**

42* Flowers always solitary; bracts membranous to herbaceous **44**

43 Palate with 2–3 prominent ridges; apex of upper lip rounded to emarginate; leaf apex rounded to acute (Qld, southern Aust.) .... **10 *U. dichotoma***

43* Palate ridges not prominent; apex of upper lip shortly bilobed to emarginate; leaf apex subulate (NT e) .... **18 *U. triflora***

44 Corolla 6–12m long, usually mauve, apex of upper lip divided into two deltoid lobes, lower lip 4-angled (WA[¤], NT) .... **17 *U. hamiltonii***

44* Corolla 15–20 mm long, white or very pale violet, apex of upper lip truncate to emarginate, lower lip transversely elliptic (Qld e) .... **11. *U. terrae-reginae***

[#] There is also another very small flowered (c. 2 mm), apparently new taxon known from further north on Cape York (J. Clarkson pers. comm.) with purple, spurred, palated flowers similar to a tiny version of the widespread *U. minutissima* Vahl., but which requires further study to determine its identity and affinities.

[†] There is some doubt that this name has been applied correctly to WA specimens and the material is currently under study.

[‡] This taxon is now recorded for WA (R. Barrett pers. comm.; FloraBase 2007).

[^] *Utricularia fistulosa* has recently been recorded (K.G.Brennan 7275) from Macadam Range, in NT.

[¤] In the Kimberley, an all-white-flowered form of *U. hamiltonii* has recently been discovered. The typical mauve-flowered *U. hamiltonii* common in the Northern Territory was not found at the Kimberley location (R. Barrett pers. comm.).

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From populations to communities: understanding changes in rainforest diversity through the integration of molecular, ecological and environmental data

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Abstract

The progressive aridification of the Australian continent during the last 30 million years has considerably reduced the amount of habitat suited to broad-leaved vegetation. The fossil record suggests that much diversity has been lost in that period, and that the extreme climatic fluctuations of the Quaternary stressed the remaining refugial areas even further. Yet, despite the considerable transformation of the surrounding environment, the rainforest remnants scattered along the east coast still contain considerable levels of biodiversity and endemism. This complex matrix of remnants reflects a long and varied history of selective pressures, and represents an ideal setting for evolutionary studies. Although the conservatism of some rainforest lineages points to localised environmental stability, it also highlights the importance of adaptive potential and selective tolerance. A number of recent case studies show that the tension between persistence and dispersal (often in combination with other factors) is an important mechanism contributing to the survival and distribution of rainforest species. This paper discusses the benefits of linking molecular, ecological and environmental data to improve both interpretations and hypotheses of current (neo) and past (paleo) distributions and relationships among rainforest plants, and how this information can be used to improve conservation and management approaches. Understanding how species and communities have survived past environmental change will be a critical step in predicting likely responses to future threats. A selection of integrative research topics that are likely to increase our predictive capacity for future change are outlined.

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Introduction: decline from dominance

Paleo-botanical studies suggest that during the Mid Eocene, closed canopy forests represented the dominant vegetation type across the Australian continent (Kershaw et al. 1991). Forests similar to those now restricted to the northern and wetter parts of Queensland were once widespread at much higher latitudes. As the Australian landmass separated from Antarctica in the Late Eocene, the formation of circumpolar currents increased the amount of moisture trapped at the South Pole as ice. This was followed by a global decline in temperature, and by increased aridification and retreat of rainforest vegetation continent-wide (Greenwood & Christophel 2005). By the Mid Miocene the extensive Western Australian paleo-drainage had dried. Rainforests disappeared from central Australia and were eventually restricted to wetter coastal habitats by the Late Miocene (Martin 2006). Evidence suggests that in the last 10 My the core rainforest areas of the Wet Tropics have remained relatively ecologically stable, while further fragmentation, aridification and loss of biodiversity took place at more southern latitudes (Kershaw et al. 2005).

Extensive macro- and micro-fossil records show that the Mid Eocene forests were dominated by families (such as Cunoniaceae, Elaeocarpaceae, Lauraceae, Myrtaceae and Proteaceae) that remain important in modern Australia (Greenwood & Christophel 2005). Floristically, rainforests are often considered as the living links to Australia's ancient past as they harbour a high concentration of primitive angiosperms (Webb & Tracey 1981). These paleo-endemics are vestiges of previously widespread taxa and are concentrated in the Wet Tropics and across the eastern border between Queensland and New South Wales (Whiffin & Hyland 1986). In some families only moderate morphological modifications have occurred during the last 55 My despite the major climatic adjustments that took place as the Australian continent traveled through 20° in latitude (Hill 2004). However, while some lineages have barely changed in morphology, the fossil record proves that their distribution has been considerably modified. For example, Oligocene and Miocene fossil floras from Victoria, New South Wales and southern and central Queensland contain endocarps of *Elaeocarpus clarkei* F.Muell. morphologically similar to the modern *E. bancroftii* F.Muell. & F.M.Bailey that is restricted to the Wet Tropics (Rozefelds & Christophel 1996, Greenwood & Christophel 2005).

Interestingly, the morphological adjustments that did take place were not necessarily in response to aridification. Hill (2004) suggested that the appearance of scleromorphy/xeromorphy in Proteaceae during the Mid Eocene (a period of high rainfall) was likely to be a response to nutrient deficient soils and/or higher light levels. These characteristics however, were an important source of evolutionary potential for adaptation to aridity, with increased diversification of sclerophyllous lineages taking place between 25 and 10 Mya (Crisp et al. 2004). More recently, molecular phylogenetic studies have contributed to the development of new hypotheses about previously unexpected relationships between dry-adapted and rainforest lineages. One such example is Tremandraceae, a former southern family of dry-adapted shrubs recently shown to be part of Elaeocarpaceae (comprising mostly rainforest trees), with the diversification of *Tetratheca*, the largest genus, putatively occurring during the major aridification phase of the Late Miocene (Crayn et al. 2006).

Because of the continental-scale climatic and environmental changes described, all remaining rainforest areas in Australia can be considered as refugia. Yet, despite covering

<1% of the land area, rainforests still contain a considerable portion of Australia's unique biodiversity (Adam 1992).

The extreme climatic events of the Quaternary

The fossil record suggests that the greatest reduction in suitable rainforest habitat and diversity occurred before the Quaternary (Hill 2004). However, the most recent ice-age caused significant adjustments to species distributions worldwide, particularly during the last 700 Ky when climatic fluctuations were more intense (Hays et al. 1976). In Australia, rather than creating extensive ice sheets, ice-ages shaped the distribution of vegetation by increasing aridity, fire frequency and fire intensity (Bowman 2000). Paleo-climatic models suggest that the changes in temperature and moisture regimes caused by glacial maxima fragmented rainforest remnants into even smaller refugia (Nix 1991). As in most other areas around the globe, some species adapted to these new conditions or dispersed to more suitable locations, while others only persisted in marginal portions of their former range or became extinct (Hewitt 2000). Well-dated marine palynological records from northern Queensland suggest that throughout the late Cenozoic, complex rainforests occupied the wetter habitats and were surrounded by extensive drier araucarian forests that functioned as a transition to true sclerophyllous vegetation (Kershaw et al. 2005). In the last 200 Ky, increased climatic instability brought about greater environmental stress and vulnerability to fire, resulting in the replacement of the araucarian forest by true sclerophyllous vegetation dominated by eucalypts. The last glacial maximum was particularly intense, with severe and persistent fragmentation revealed by *Eucalyptus* intrusions in current Wet Tropics rainforest areas as recently as eight thousand years ago (Hopkins et al. 1993). The intensity of these more recent events is likely to have caused further extinctions (Kershaw 1994).

During the brief inter-glacials (such as the one we are currently in) climatic conditions improved and refugial populations could expand into newly available habitat. The success of post-glacial expansions depended on a range of factors such as recruitment and dispersal potential, and played an important role in defining modern-day distribution patterns. Extensive palynological records from the Northern Hemisphere show that tree species responded differently to climate change, tracking their individual habitat requirements according to their dispersal capability (Hewitt 1996). During this expansion process, transitional plant communities that were considerably different to current ones were established with the help of small populations that persisted within microclimate pockets in areas otherwise considered as unsuitable. Recent studies suggest that a predicted loss of 'core' habitat does not necessarily imply population extinction (although it certainly implies greater vulnerability), and that in order to understand temporal distributional changes of plant communities, it is essential to appreciate the tolerance of single species to environmental fluctuations (Stewart & Lister 2001). Similar species-level palynological records have not yet been identified for the Australian paleo-flora, as the focus of most studies has been on broad vegetation structure. As we await more detailed palynological investigations on rainforest taxa, we can assume that suitable circumstances existed for the survival of small refugial populations along the eastern coast of Australia.

The molecular revolution: fine-scale evolutionary dynamics

Paleo-ecological, biogeographic and systematic studies have provided valuable information on the evolutionary and distributional shifts that shaped the Australian flora. However, if we are interested in the factors impacting on the survival/extinction of species, we must also consider the fine-scale influence of selective biotic and abiotic processes. The advances in molecular genetics over the past 20 years have significantly contributed to this goal. For example, reciprocally monophyletic populations (evolutionary significant units) can be identified by sampling selected loci prone to high substitution rates but non-recombinant and uni-parentally inherited (Moritz 1994). These genetically distinct groups identify historically isolated populations and define the location of barriers to gene flow (such as those established by changing climatic conditions). The availability of complementary fossil and molecular data and the recent development of improved analytical approaches (Sanderson 2003) provide the opportunity to explore the temporal dimension of these evolutionary processes.

Comparative studies on co-distributed species can make use of the genetic signatures left by different expansion patterns to identify the locations of refugia, the factors affecting expansion patterns and the adaptive potential of these taxa. In the Northern Hemisphere, haplotypic data from a range of maternally-inherited chloroplast loci have been used to track post-glacial re-colonisation patterns in a considerable number of tree species, confirming models previously suggested by palynological data (Petit et al. 2005). Interestingly, comparative studies in *Quercus* have concluded that during the last glaciation a more complex matrix of localised refugia (and consequently greater genetic diversity) was maintained in California than in Western Europe, highlighting how habitat availability and different life-history combinations can influence re-colonisation outcomes (Grivet et al. 2006). Similar studies are still limited in Australia. An overview of plastid DNA variation across the natural range of Tasmanian eucalypts from section *Maidenaria* showed that genetic variation correlates more with geography than taxonomy (McKinnon et al. 2001). This regional haplotype-sharing pattern suggests that extensive hybridisation took place among local eucalypts following the latest ice age (McKinnon et al. 2004), a pattern reminiscent of that found in the European oaks (Petit et al. 2002).

An Australian rainforest perspective

Australian rainforest habitats provide an ideal setting for evolutionary studies (Schneider et al. 1998). They have high amounts of taxonomic diversity and endemism and, as suggested by fossil evidence, include ancient lineages that have been continuously present in the region (Hill 2004, Greenwood & Christophel 2005). Furthermore, rainforests are currently distributed across a matrix of differentially sized and spaced remnants that reflect a long and varied history of environmental disturbance and selective pressures (Moritz & McDonald 2005).

Until recently, most of the molecular research investigating the history and dynamics of Australian rainforests was focused on the fauna of the Wet Tropics. Phylogeographic studies on a number of low-vagility vertebrates (including habitat-specialist birds, lizards and frogs) detected significant genetic disjunction between populations distributed across a previously identified (Nix 1991) biogeographic barrier, the Black Mountain Corridor (BMC, a strip of low-lying land between Cairns and Mossman that interrupts the Great Dividing Range; Schneider et al. 1998). Molecular divergence was ascribed to multiple vicariance episodes mostly near the BMC area, with the majority of speciation events originating before the Pleistocene. This suggests that the climatic fluctuations of the Quaternary generally emphasised existing divergence patterns rather than creating new ones (Schneider et al. 1998, Schneider & Williams 2005). The shallow genetic divergences measured between single putative refugia, and the lower genetic diversity in southern populations also suggest that a loss of suitable habitat during glacial maxima (and likely decline in species richness) was followed by rapid re-colonisation (Moritz & McDonald 2005). As these events are affected by the ecological characteristics of each species, it has been suggested that future studies should also pay attention to the ecological factors likely to impart selective constraints rather than focus on geographic isolation alone (Schneider et al. 1999).

The available fossil evidence from the Australian rainforest flora also points to an historical decline in diversity, although limited examples of recent speciation exist within southern rainforests (Rossetto 2005, Savolainen et al. 2006). To date, no phylogeographic research on the Australian rainforest flora has been published. However, a few studies assessing overall genetic diversity across single species have detected significant north/south genetic disjunctions (*Fontainea australis* Jessup & Guymer, Rossetto et al. 2000; *Araucaria bidwillii* Hook., Pye & Gadek 2004; *Nothofagus moorei* (F.Muell.) Krasser, Taylor et al. 2005). A more recent study sampled the entire distribution of two related and co-distributed rainforest trees, documenting substantial discrepancies in genetic differentiation across biogeographic barriers such as the BMC (Rossetto et al. 2007). While *Elaeocarpus largiflorens* C.T.White revealed an abrupt genetic front between two morphologically distinct subspecies separated by the BMC, the same barrier was inconsequential to *E. angustifolius* Blume (which showed lower genetic differentiation across a much wider geographic gap). A broader study in progress is comparing genetic disjunctions across 11 tropical *Elaeocarpus* species representing a range of habitat preferences and life-history traits combinations. Interesting preliminary patterns include north/south genetic disjunctions for higher-altitude species (as previously shown in *E. largiflorens*), as well as an unexpected lack of impact of fruit type on genetic structure (Rossetto et al. in prep.).

Understanding evolutionary patterns at temporal and geographical scales is only the first step as it is essential to relate these patterns to causal factors. Simulations investigating the expansion potential of trees show that models that take into account life-history traits relating to dispersal and life-cycle are more realistic and more likely to provide the correct interpretation of molecular data (Austerlitz & Garnier-Gere 2003). Thus in order to discover the factors regulating landscape connectivity, it is important to develop more studies targeting range-wide sampling across related species representing diverse habitat preferences and life-history traits.

Evolutionary ecology: finding meaningful patterns

Multi-species studies integrating ecological, molecular and environmental evidence can identify broad evolutionary patterns, and recognise the mechanisms that influence the survival of populations and species. Recent work is uncovering broad correlations between life-history traits and the distribution of taxa. For instance, a study comparing sexual systems across Australian tropical trees (1113 species from 83 families) found that the incidence of monoecy is significantly higher in Australia than in other tropical floras (Gross 2005). Although phylogeny might be partly responsible for this (about 50% of the monoecious taxa are from two families), Gross (2005) suggested that the reliance on inefficient insect pollinators could have favoured the maintenance of monoecy. Another large-scale rainforest study including 258 species from the Nightcap Ranges (northern NSW), identified the life-history traits associated with persistence and dispersal as the most influential in describing the current distribution of locally rare trees (Rossetto & Kooyman 2005). The results suggest that major environmental changes have been important selective drivers on large-fruited species within these southern rainforests. It can be assumed that while large-seeded plants can establish more efficiently, lower seed production and the absence of dispersal organisms reduce expansion capability after a bottleneck. As a result, the large-fruited species that survived habitat contractions are likely to be the ones that could enhance their competitiveness through in-ground stem persistence. Fine-scale molecular studies on narrow endemic taxa are supporting this hypothesis (Rossetto et al. 2004a, Rossetto & Kooyman 2005, Rossetto et al. in prep.). For instance, the high levels of diversity within small, isolated populations of *Eidothea hardeniana* P.H.Weston and *Elaeocarpus sedentarius* could be symptomatic of a strategy involving the reliance on self-replacement of individuals through resprouting rather than recruitment. The lack of correlation between genetic and geographic disjunctions despite the presence of strong population-level genetic autocorrelation, also highlight the impact of limited dispersal.

The persistence niche

The importance of persistence is often neglected while that of recruitment is emphasised, yet many ecosystems are dominated by resprouters (Bond & Midgley 2001). Vegetative reproduction provides a competitive edge by allowing the sharing of resources between connected ramets, and can be considered as an alternative lifecycle loop that allows persistence in species that are not able to complete a normal life-cycle. The persistence niche is suitable to a range of disturbance regimes, enables species to tolerate long periods without recruitment, allows regeneration in unsuitable conditions and can reduce the loss of population-level genetic diversity (Bond & Midgley 2001). This strategy can be particularly suitable to species constrained to less than ideal habitats, and Johnson and Lacey (1983) suggested that it might be an important long-term survival strategy for rainforest trees.

Resprouting is a relatively safe escape route under suboptimal conditions but prolonged clonal growth through environmental suppression of sexual reproduction can lead to monoclonal populations. There are some interesting examples of extreme clonality in the Australian flora. For example a range of molecular approaches could not identify any variation across individuals of *Wollemia nobilis* sampled from all known sites (Peakall et al. 2003). Similar circumstances were discovered for *Elaeocarpus williamsianus* Guymer, a tree restricted to a number of disjunct and mostly disturbed rainforest remnants in northern NSW. A genetic study found that all populations but one consisted of single clones and since this is a preferential outcrossing species, viable seed could not be set (Rossetto et al. 2004a). *E. williamsianus* is now locked into an evolutionary dead-end loop: long- and short-term disturbance events have favoured excessive clonality that prevents sexual reproduction and long distance dispersal. In turn, limited dispersal prevents range expansion and the potential gene flow which would re-establish a balance between vegetative and sexual reproduction.

The importance of dispersal

There is increasing evidence that expansion mechanism and habitat preference are among the main factors affecting the temporal distribution and the diversification potential of plant species (Pearson 2006). Dispersal of propagules enables genetic exchange (thus reducing vicariant divergence and inbreeding), as well as expansion to newly available habitat and recovery after unfavourable circumstances. For instance, rainforest trees that produce fleshy, highly dispersible fruits can be expected to have lower levels of between-population genetic differentiation than species with less palatable fruits (Shapcott 2000). Thus fruit morphology can affect current distribution patterns, and mal-adaptation through lack of dispersers can explain rarity in the vertebrate-poor rainforests of northern NSW (Rossetto et al. 2004a, Rossetto & Kooyman 2005, Rossetto et al. submitted), although it does not imply short-term extinction (as previously suggested; Archer et al. 1994). It is important to remember that inference of expansion potential from fruit morphology alone can be unsatisfactory, as capacity for dispersal is not necessarily synonymous with effective dispersal (i.e. including establishment). Unfortunately, information on dispersal efficiency of the Australian rainforest flora is still limited although an increasing number of recent studies are measuring active fruit dispersal by Wet Tropic frugivores (Westcott & Graham 2000, Westcott et al. 2005). The tension between persistence and dispersal is likely to be an important mechanism contributing to the current distribution of many rainforest species, but clearly there are other factors that also need to be investigated.

These early studies are showing that paleo-endemic species can survive for a long time within small populations (Rossetto et al. 2000, Rossetto et al. 2004a, Rossetto & Kooyman 2005). This suggests that single populations, or even whole new species (Weston & Kooyman 2002), can still be found within moderately-sized vegetation remnants, and that small populations are not doomed as they can persist and maintain potential for future expansion (if and when suitable conditions arise). However, it is important to stress that this apparent resilience does not make restricted populations less vulnerable to stochastic events and anthropogenic disturbance.

Reacting to the biodiversity crisis

During the last 150 years the impact of logging, clearing and urbanisation has further reduced the extent of rainforest vegetation in Australia (Connelly & Specht 1988). This is particularly true for the Big Scrub of northern NSW (which covered an area of over 70 000 ha prior to European settlement) where widespread clearing has restricted rainforest vegetation to approximately 1% of its original distribution (Lott & Duggin 1993). Rainforests worldwide are subject to increasing external pressures and degradation that dissect continuous species distributions into isolated fragments (Whitmore 1997, Arnold & Rossetto 2002, Rossetto et al. 2004b) and despite recent controversy on the true extent of the global rainforest biodiversity crisis (Wright & Muller-Landau 2006; but see Laurence 2006), we now recognise that drastic environmental modifications linked to impending climate change threaten the integrity and long-term sustainability of rainforest ecosystems. For instance, in the Wet Tropics where the altitudinal gradient is the most significant factor explaining fauna compositional patterns (Williams et al. 2003), climate change scenarios (with temperature increasing up to 5°C in the short term) predict a significant reduction in suitable upland conditions and the potential disappearance of entire habitat types. Consequently, rainforest conservation and management faces challenges at two temporal levels: the contemporary, dealing with current threatened species lists and habitat fragmentation, and the future, dealing with the predicted decline of already small habitat remnants.

Understanding likely responses to future threats is crucial to conservation planning, and one of the main challenges for conservation biology will be to anticipate environmental change and adjust management approaches accordingly. By appreciating how past climatic cycles have affected selective biotic and abiotic pressures and consequently the survival and distribution of species and ecological communities, we will be able to develop predictive models that determine vulnerability to future change. An increasingly common response to the problem is the development of multi-species recovery plans, which hopefully will be followed by multi-species implementation projects. Biologically meaningful multi-species approaches are being explored, such as the one based on trait-based functional groups currently being developed for the threatened flora of the Border Ranges (Kooyman & Rossetto in prep.). In the long-term, a focused approach involving integrative research will facilitate the management of threats and risks at the species, multi-species and the ecosystem levels.

Conclusion: where to from here?

Fossil evidence shows a considerable level of conservatism in the Australian rainforest flora despite gradual long-term and intensive short-term environmental change. This suggests the presence of localised environmental stability, but also points to the adaptive potential of some lineages that have survived the evolutionary sifting of severe climatic cycles. It can be expected that a range of key biological (evolutionary) factors played an important role in the endurance of the remaining rainforest flora. To better understand the factors influencing evolutionary processes, future research should include:

1) Phylogenetically structured multi-species molecular ecology studies targeting important biogeographic barriers and selected functional groups. The discovery of repeated patterns of genetic divergence will identify landscape features of evolutionary significance and selectively important life-history traits. The availability of relevant paleo-ecological data would also enable the accurate dating of these events.

2) Evaluations of multiple associative patterns among selected life-history traits and the distribution of species (and/or genes). This will contribute to the identification of the major factors likely to affect the evolutionary response to changing environmental circumstances.

3) The development of models (based on appropriate levels of ground-truthing and in-situ data gathering) that can differentiate between potential and realised niches for species and ecological communities. This will improve our understanding of the level of tolerance of species and communities, and enable us to predict the impact of future environmental and climatic change.

On their own, these are important areas of research but the greatest scientific benefit will arise from developing experimental designs that combine them all. The Australian rainforest flora provides a unique evolutionary scenario for this type of research; however these approaches are suitable and relevant to a broad range of vegetation types.

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Two new species of *Commersonia* (Malvaceae *sensu lato*) from south-eastern Australia

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Abstract

Commersonia amystia C.F.Wilkins & L.M.Copel., and ***C. breviseta*** C.F.Wilkins & L.M.Copel., from south-eastern Australia, are described as new and illustrated. Notes are given on their ecology and conservation status, and the distribution of each species is mapped.

Introduction

Recent cladistic analyses of morphological data (Wilkins 2002) and *ndh*F sequences (Whitlock et al. 2001) of the Lasiopetaleae confirm that together *Rulingia* R.Br. and *Commersonia* J.R.Forst & G.Forst. form a monophyletic group. Although only a few species were included in each analysis, both studies suggest that species of the two genera are intermingled, such that neither is monophyletic as currently delimited. Results of additional unpublished morphological and molecular phylogenetic analyses (Wilkins & Whitlock in prep.), with near exhaustive sampling of species in both genera, overwhelmingly supports these previous findings of monophyly of the combined *Rulingia–Commersonia* clade and non-monophyly of each genus.

The two new species described here, *C. amystia* and *C. breviseta*, are closely related to the type of *Rulingia*, *R. dasyphylla* (Andr.) Sweet. These three species along with *R. hermanniifolia* (J.Gay) Endl., *R. prostrata* Maiden & E.Betche, *R. rugosa* Steetz and *R. salviifolia* (Steetz) Benth., will be included in *Commersonia* in the near future (Wilkins & Whitlock in prep.). To avoid later combinations the two new species are here described as *Commersonia*.

The majority of the approximately 45 currently described species of the closely related genera *Commersonia* and *Rulingia* are confined to Australia. *Commersonia bartramia* (L.) Merr. is recorded in Australia, South East Asia and islands of the Indo-Pacific.

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There are three taxa that are closely related to *C. bartramia,* which occur in New Guinea (*C. novoguinensis* (Gilli) Guymer), in Vanuatu (*C. obliqua* Guymer) and in Tahiti (*C. bartramia* var. *tahitensis* L.J.Dorr). *Rulingia madagascariensis* Baker is endemic to Madagascar.

From verbal communications and examination of herbarium material it appears that many taxa of *Rulingia* are poorly understood, with heterogeneous elements in the same species folders. It is difficult to distinguish between the seven species mentioned above without fruiting and flowering material and identification is further complicated by tri-lobed juvenile leaves, which have variable shapes and hair densities. A key for species delimitation including morphological characters for separating species is provided in a revision nearing completion.

Specimens of the two new species *C. breviseta* and *C. amystia* were included in the Flora of SE Qld (Stanley & Ross 1986, p. 87) and in Names and Distribution of Queensland Plants (Henderson 2002) as *R. hermanniifolia.* This latter species is restricted to an area between Sydney Harbour National Park and Jervis Bay in New South Wales. NSW collections of *C. breviseta* were determined as *R. dasyphylla, R. hermanniifolia,* or *R. rugosa* and included as such in The Flora of New South Wales (Harden 2000). The collection of *C. breviseta* from Egan Peak Victoria was determined as *R. dasyphylla,* a species included in The Flora of Victoria (Walsh & Entwistle 1996).

To clarify this situation these two new species are described prior to publication of a revision of *Commersonia/Rulingia*. In addition, *C. amystia* is rare and has special conservation requirements.

Methods

Collections of *R. dasyphylla* and closely related species from AD, BM, BRI, DNA, K, LIV, MEL, NE, NSW, NY, PERTH and W have been examined in this study, including type specimens of *R. pannosa*, *R. prostrata*, *Thomasia salviifolia* Steetz (base name for *R. salviifolia*) and *R. rugosa*. Herbarium abbreviations follow Holmgren et al. (1990). The authors have collected and studied the habit and morphological characters of *C. breviseta* and *C. amystia* in their natural habitat. Floral measurements are from rehydrated herbarium collections and vegetative measurements are from dried specimens. Density of leaf hairs is defined as scattered when the hairs are well separated, moderately dense when the hairs are just touching laterally, dense when the hairs strongly overlap with the epidermis remaining visible, and tomentose when hair density is such as to conceal the epidermis. Fruit measurements include the length of the setae on the outer surfaces.

The distribution maps were compiled from the Online Map Creation internet site (http://www.aquarius.ifm-geomar.de/omc/) using GMT (Generic Mapping Tools) software.

Commersonia amystia C.F.Wilkins & L.M.Copel., ***sp. nov.***

Filamentis villosis et fructibus magnis pilis densis simplicibus in setis longis dispositis R. rugosae affinis, sed floribus per inflorescentiam paucis petalae basi supra et infra locum affixum valde gibbosa nec tantum supra locum affixum differt.

Type: New South Wales: North Western Slopes: Howell, 20 km SSW of Inverell, 29°56'S, 151°01'E, *L.M. Copeland 3615*, 16 Oct 2003 (holo: NSW; iso: BRI, CANB, K, MEL, NE, PERTH) (Specific locality details withheld for conservation reasons).

Rulingia hermanniifolia auct. non (J.Gay) Endl.: *Rulingia salviifolia auct. non* (Steetz) Benth., *Rulingia dasyphylla auct. non* (Andr.) Sweet, Stanley & Ross, Fl. SE. Qld p.87 (1986); Henderson, Names & Distrib. Qld Pl., Algae & Lichens, p.192 (2002)

Rulingia sp. (Single NP L.M. Copeland 2009) in Clarke et al. (2000)

Dwarf shrub, 10–30 × 60–70 cm, prostrate to decumbent. *Branchlets* densely hairy, with sessile, white, stellate hairs with 4–6 erect arms to 0.5 mm long, above smaller, sessile, white, stellate hairs and inconspicuous, white, clavate glands *c.* 0.15 mm long; glabrescent with red-brown, longitudinal, irregular, fine ridging. *Stipules* late caducous, green throughout, or with red apex, ovate-lanceolate to narrow-lanceolate, rarely bifid, 0.8–4.5 × 0.3–1.5 mm, adaxial surface with sparse, appressed, white, stellate hairs with 1 or 2 arms to 0.3 mm long, and rarely with sparse, white, clavate glands c. 0.1 mm long; margin with dense, white, 1–3 armed hairs to 0.7 mm long, abaxial surface with dense, white, stellate hairs with 3–8 erect arms to 0.5 mm long. *Mature leaf* with petiole 0.8–2.5 mm long, hairs as on distal branchlets; blade scarcely discolorous, mid green over pale green, narrowly-ovate, rarely ovate, 2.5–31.9 × 1.5–9.2 mm, base cordate, scarcely oblique; abaxial surface densely hairy to tomentose, hairs sessile, white, stellate with *c.* 6 erect arms up to 0.7 mm long on midrib, up to 0.4 mm long on blade, above a dense layer of smaller, white, stellate hairs; adaxial surface moderately hairy, with hairs sessile, white, stellate, with 1–8 erect arms up to 0.6 mm long, scattered above smaller, stellate hairs, glands absent or if present, then scattered, white, clavate and up to 0.1 mm long; margin sinuate or irregularly serrate, recurved, hence appearing entire, flat or undulate, apex obtuse or acute. *Juvenile leaves* trilobed, serrulate, up to 53 × 31 mm. *Inflorescence* a leaf-opposed cyme, 9.2–39.1 mm long, flowers (1) 2–4 (6). *Peduncle* 2.5–18 mm long, extending to 10–31 mm with fruit; *pedicel* 2–8.5 mm long; both peduncle and pedicel densely hairy, hairs sessile, white, stellate, with *c.* 6 erect arms, 0.35–0.7 mm long, over moderately dense, smaller, white, stellate hairs, and white clavate glands with red apex, up to 0.25 mm long. *Bract* inserted towards base or middle of pedicel, ovate or narrowly ovate, green, membranous, becoming red-brown, 1.8–4.2 × 0.7–2.5 mm, surfaces as in stipules above, margin entire. *Flower bud* base strongly cordate from deep pouching to contain gibbous petal base; apex sub-acute. *Epicalyx* absent. *Calyx* white throughout or base pink, 3.9–5.8 mm long, lobes elliptic, 3–4.2 × 1.6–3.3 mm (70–82% of total calyx length), apex obtuse or sub-acute; tube with deep pockets; abaxial surface has base with dense, sessile, white, stellate hairs, with 6-8 erect arms to 0.6 mm long, above smaller white, stellate hairs and occasional stalked, clavate glands to 0.2 mm long, towards apex of lobe with shorter hairs; adaxial surface with nectary of dense, clumped, clavate glands over base of rib and both sides; base of calyx and centre of lobe with dense, appressed or erect, white hairs with 1–4 arms to 0.35 mm long, and towards the margin and apex of lobes with dense, white, simple or stellate hairs, with arms to 0.15 mm long. *Petals* white, 1.8–3.2 × 2.2–3.2 mm, base becoming pale pink, obovate when flattened, very strongly gibbous (cupped) both above and below attachment to calyx; apical ligule narrowly-oblong, remaining white, 0.9–1.8 × 0.2–0.4 mm, inner and outer surfaces stellate hairy. *Staminal tube* white or pale pink, 0.1–0.4 mm long. *Staminodes* five, one inserted between each stamen, ovate, white, 2.3–2.9 × 0.6–0.8 mm, inner and outer surfaces stellate hairy. *Filaments* 0.6–1.2 × 0.15–0.25 mm, with white, stellate hairs. *Anthers* ventri-fixed, broadly-elliptic, dark red, 0.4–0.7 × 0.5–0.7 mm, dehiscence from latrorse slits, pollen yellow. *Ovary* 5-celled, ovoid, 0.6–1 × 0.6–1 mm, locules fused laterally with no indentation, central axis with slight gap, outer surface green with pre setae outgrowths. *Ovules* 2–6 per cell. *Styles* 5, green, 0.7–1.3 mm long, glabrous, free at base, fused at sub-capitate stigmas. *Fruit* sub-globose, or ellipsoid, red-brown, wings absent, outer wall woody (*c.* 0.5 mm thick), capsule 5.5–6 × 7–7.2 mm excluding setae (bristles with hairs), 8–10 × 11.5–13 mm with setae included, outer surface with dense, soft, white, stellate hairs with arms up to 0.4 mm long, below dense setae, all over surface, longer at the sides (up to 3.0 mm long) than the apex (0.5–1 mm long); setae red-brown, with an apical, stiff, white, *c.* 6-erect-armed, stellate hair and shaft with dense, white, 1–3 erect-armed hairs. *Seed* exotesta brown with dark brown tubercles, glabrous, 1.7–1.8 mm long, 1.2–1.3 mm diam. *Aril* a cream, translucent lobe flared from hilum *c.* 0.3 × 0.8 mm (Fig. 1)

Specimens examined: QUEENSLAND: Lyra, *Blake 21103*, 3 Nov 1959 (CANB); Stanthorpe Rd, Ballandean, *Clemens 44484*, 16 Oct 1944 (K); Mt Fletcher, NW of Ballandean, *Halford Q2287*, 20 Oct 1994 (BRI, NSW); SW of Stanthorpe, near. Severn River, *Pedley 1466*, 29 Oct 1963 (BRI); Ballandean, *Williams s.n.* (NE30519A), 23 Aug 1975 (BRI, CANB, NE, NSW); Bald Rock Creek, Wyberba, *Williams NRAC 3*, 1 Oct 1994 (NE). NEW SOUTH WALES: Single National Park, 35 km NW of Guyra, *Clarke & Knox s.n.* (NE81450), 27 Aug 2003 (NE): ibid., *Copeland 2009 & Noble*, 3 Nov 1999 (CANB, NE, NSW); ibid., *Copeland 2485*, 2 Mar 2000 (NE); ibid., *Fethers 28*, 22 Jun 2000 (CANB); Howell, 20 km SSW of Inverell, *Clarke & Knox s.n.* (NE81449), 27 Aug 2003 (NE); ibid., *Copeland 2753*, 22 Nov 2000 (BRI, CANB, NE, NSW); Howell, *Miss Munsie 17*, Oct 1913 (NSW). (Specific locality details of all specimens withheld for conservation reasons).

Distribution: *Commersonia amystia* is currently known from two populations in the Inverell district of northern New South Wales and three populations in the Ballandean – Stanthorpe districts of southern Queensland. (Fig. 2)

Habitat and ecology: all plants observed grow in skeletal, sandy-loams amongst crevices of granitic and acid volcanic outcrops. Altitude ranges from 700 m to approximately 1050 m. Associated species include *Eucalyptus prava*, *Harmogia densifolia*, *Acacia triptera*, *Homoranthus prolixus*, *Lepidosperma laterale*, *Actinotus gibbonsii* and *Cheilanthes sieberi*.

Commersonia amystia appears to be an obligate seeder that is killed by fire but germinates in abundance shortly thereafter. At the type locality hundreds of plants were observed flowering approximately one year after a wildfire event but these appeared to be senescing two years later. The same pattern has been observed in Single National Park where all adult plants appeared to be killed by fire in 2003 but numerous seedlings were observed shortly after in 2004.

Phenology: this species is recorded as flowering in August, September and October with young fruits usually forming in October and November.

Conservation status: the species is currently known from fewer than 300 individuals in New South Wales and an unknown number of plants in southern Queensland. The only reserved population is in Single National Park where approximately 30 plants are known from a single rocky outcrop. Threats to *Commersonia amystia* include an inappropriate fire regime, grazing by feral goats and disturbance by feral pigs. This species is thought to be rare and will be submitted to relevant conservation bodies as having special conservation needs.

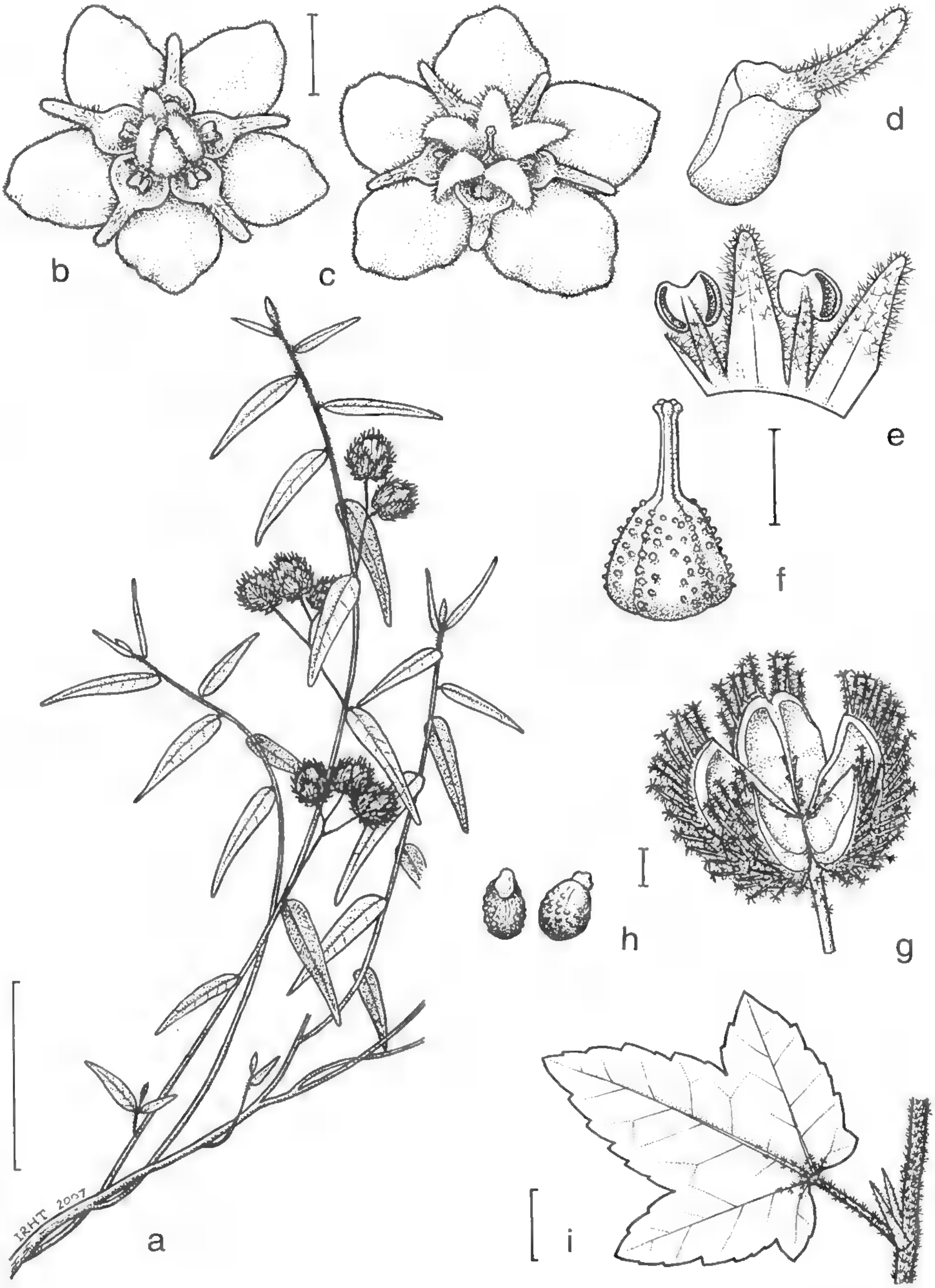

Fig. 1. *Commersonia amystia*, **a,** habit, showing fruiting branchlet; **b,** flower with staminodes incurved over ovary at dehiscence; **c,** flower with staminodes spread; **d,** petal with deeply gibbous base; **e,** stamens and staminodes; **f,** gynoecium; **g,** fruit with seed shed; **h,** seed; **i,** juvenile leaf. (a, g, h, from *Williams NE 30519*; b - f from type collection, *Copeland 3615*; i from *Clarke NE 81449*). Scale bars: a = 5 cm; b, c =2 mm; d - h = 1mm; i = 1 cm.

Etymology: the specific epithet *amystia* is Greek for large cup, and relates to the deeply gibbous petal base.

Comparison with similar species: *Commersonia amystia* appears to be most closely related to *Rulingia rugosa* in having hairy filaments, the lower surface of the leaves with a similar tomentose surface rather than dense hairs as observed in *R. dasyphylla*, and in having large fruits with dense, simple hairs on long setae. It differs from *R. rugosa* in having smooth, thin, pale green leaves, rather than rugose, mid green leaves, (1)2-4(6) flowers per inflorescence rather than 7–15, and a petal base that is obovate when flattened and strongly gibbous below and above its basal attachment, rather than ovate and gibbous only above the attachment.

Notes: *Commersonia amystia* was recognised as a new species *Rulingia* sp. (Single NP, L.M. Copeland 2009) from collections in the Single National Park / Howell areas by Clarke et al. (2000).

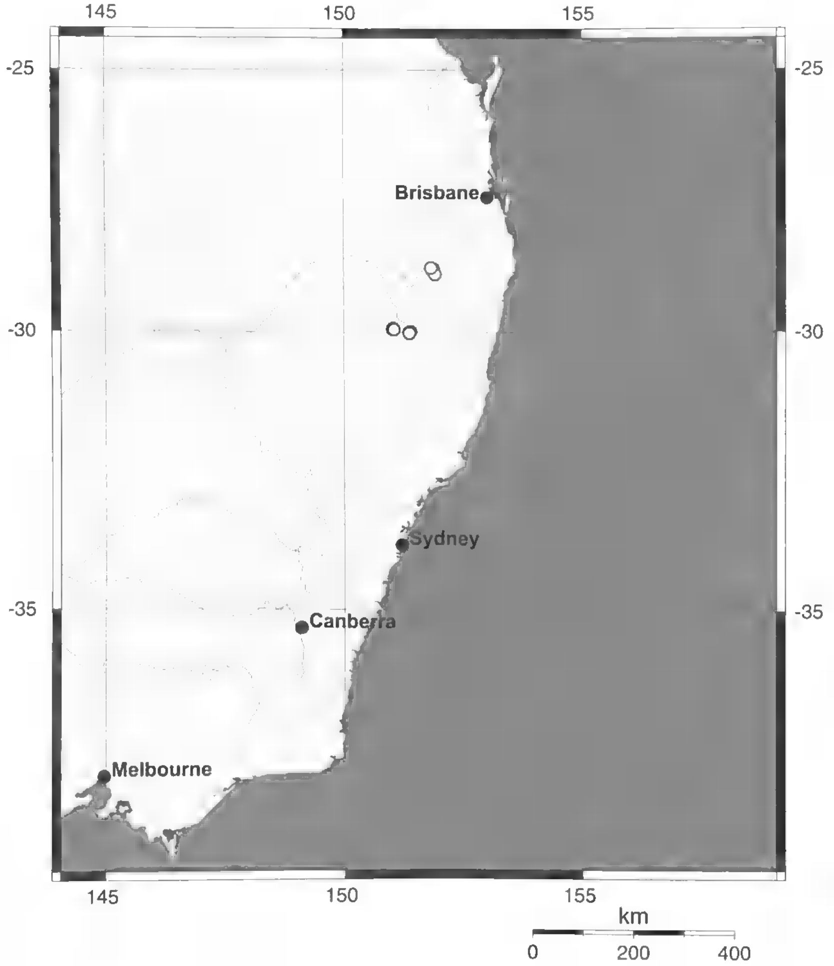

Fig. 2. Distribution of *Commersonia amystia.*

Commersonia breviseta C.F.Wilkins & L.M.Copel., ***sp. nov.***

Fructibus minoribus setis ad 0.9 mm longis, pilis et glandulis scapi paucis R. hermanniifoliae similis, praecipue differt setis paucis ad apice fructi praecipue praeditis, ad invicem setis densis totae paginae, et foliis flexilibus nullimodo chartaceis.

Type: QUEENSLAND: Darling Downs district: Mt Norman, Girraween National Park, 28°52'S, 151°57'E, *C.F. Wilkins 2053, L.M. Copeland & B.A. Whitlock,* 21 Sep 2004 (holo: BRI; iso: CANB, K, MEL, NE, NSW, PERTH). (Specific locality details withheld for conservation reasons)

Rulingia hermanniifolia auct. non (J.Gay) Endl.: Stanley & Ross, Fl. SE. Qld p. 87(1986); Henderson, Names & Distrib. Qld Pl., Algae and Lichens, p. 192 (2002)

Rulingia dasyphylla auct. non (Andrews) Sweet, Harden, Fl. of NSW, p.p. 305-306 (2000), Walsh & Entwistle, Fl. of Victoria, p.p. 329-330 (1996); *Rulingia rugosa auct. non* Steetz, Harden, Fl. of NSW, p.p. 305-306 (2000).

Shrub, erect, 30–300 × 70–180 cm. *Branchlets* densely hairy or tomentose surface of white, sessile, stellate hairs with 3–6 erect arms up to 1.3 mm long, above smaller, white hairs and scattered, white, clavate glands up to 0.15 mm long; branches red-brown, glabrescent with longitudinal, irregular, fine ridging and lenticels. *Stipules* caducous, green with red apex, or red throughout, narrowly-lanceolate or ovate-lanceolate, rarely bifid, 1.5–8.5 × 0.4–1.9 mm, inner surface with scattered to dense 1–4 -armed, appressed, white hairs 0.3–0.7 mm long, and scattered, clavate glands to 0.1 mm long; outer surface and margin with dense, 2–6 erect-armed, white stellate hairs, arms up to 1.3 mm long. *Leaf* with petiole 1.1–6.1 mm long, hairs as on distal branchlets, mature blade mainly narrowly-elliptic, or ovate, 8–24.1 × 1.4–7.5 mm, base scarcely oblique, scarcely cordate or obtuse; abaxial surface densely hairy to tomentose with white, or white with tan centred, sessile, stellate hairs, with 6 erect arms up to 0.9 mm long, above dense, layer of small, white, stellate hairs, and rib with sparse pink, clavate glands present or absent; adaxial surface slightly rugose, with dense, white, sessile, stellate hairs with 1–6 erect, arms up to 0.9 mm long, above smaller hairs and medium density, orange-red-tipped, clavate glands up to 0.1 mm long; margin irregularly serrulate, recurved, apex rounded-acute or obtuse, juvenile leaves conspicuously tri-lobed, 45–110 × 20.1–45.1 mm. *Inflorescence* a leaf-opposed cyme, 8–35 mm long, flowers 4–16. *Bud* base cordate, apex rounded. *Peduncle* 2.5–6.2 mm long (4.5–16.8 on fruiting inflorescence). *Pedicel* 2–6.3 mm long (6–14 mm fruiting). Both peduncle and pedicel with dense, sessile, stellate hairs, 6–12 erect arms up to 1.1 mm long, over smaller white, stellate hairs and scattered to medium density, white, red-tipped, clavate glands to 0.3 mm long. *Bract* inserted towards base of, or mid pedicel, narrowly-ovate, ovate, 3.6–7.8 × 0.3–1.3 mm, surfaces as in stipules above. *Epicalyx* absent. *Calyx* base green, lobes with pink margins and white centre, 3.4–6.3 mm long, lobes ovate or elliptic, *c.* 65–71% of total calyx length, of variable width, 2.6–4.3 × 1.3–2.7 mm, apex acute; abaxial surface with dense, white, stellate hairs with 6 erect-arms to up 0.8 mm long, over smaller, white hairs and scattered, red-tipped, clavate glands, 0.2–0.3 mm long; adaxial surface with nectary of dense, clumped, clavate glands on the base and both sides of the rib, calyx base and central lobe with dense, white, 1–3 -armed, appressed, hairs up to 0.35 mm long, and towards the margin and apex with dense, 1–4 -armed, erect, white, simple hairs, up to 0.15 mm long. *Petals* 2.3–3.4 × 1.7–2.7 mm, cupped base pale yellow, elliptic when flattened, strongly gibbous incurved around stamen; ligule white, then becoming pale or dark pink, ligule linear-oblong, 1.3–2.3 × 0.25–0.5 mm.

Staminal tube 0.15–0.5 mm long. *Staminodes* five, one inserted between each stamen, white, ovate, both surfaces densely stellate hairy, 2–2.6 × 0.5–0.9 mm. *Filaments* white, glabrous, 0.9–1.4 × 0.1–0.2 mm. *Anthers* dark red, ventri-fixed, broadly-elliptic, 0.6–1 × 0.7–0.85 mm, dehiscence from latrorse slits, pollen yellow. *Ovary* 5-celled, ellipsoid, 0.6–0.8 × 0.7–0.8 mm, locules fused laterally with no indentation and with a gap at the central axis, outer surface green with pre setae outgrowths. *Ovules* 2–4 per cell. *Styles* 5, green, 0.5–1.3 mm long, glabrous, free at base, fused at capitate stigmas. *Fruit capsule* loculicidal, ellipsoid, brown, 2.5–3.5 × 4.3–5.5 mm, thick, woody wall to 0.4 mm thick, with scattered to moderately dense, soft, white, stellate hairs covering the outer surface of fruit and scattered, clavate glands up to 0.1 mm long present or absent, beneath scattered to moderately dense, short setae towards the upper half of the fruit, 0.5–0.9 mm long, brown, with an apical, white, 6–12 -armed stellate hair and scattered, 2–4 –armed, stellate hairs and / or red, clavate glands up to 0.1 mm long, wings absent. *Seed* dark brown, 1.6–1.8 mm long, 1.0–1.2 mm diam., exotesta strongly tuberculate, glabrous, with fine, longitudinal ridging. *Aril* a white, translucent lobe flared from hilum, *c.* 0.2 × 0.7 mm (Fig. 3).

Specimens examined: QUEENSLAND: Slopes of Mount Norman, Girraween National Park. *Blake 23710*, 4 Nov 1971 (BRI, K, NSW); Girraween National Park, along walking trail to Mt Norman, *Wilkins 2052, Whitlock & Copeland*, 30 Oct 2004 (BRI, PERTH). NEW SOUTH WALES: Washpool National Park, Granite Lookout, *Copeland 3595 & Clarke*, 5 Sep 2003 (BRI, CANB, MEL, NE, NSW); Gibraltar Range National Park, summit of Hamburger Rock, *Copeland 3893*, 29 Jan 2005 (BRI, CANB, NE, NSW, PERTH); 1 km SW of Robinsons Knob, New England National Park, *Copeland 2213 & Noble*, 1 Dec 1999 (NE); Yowaka River, *Mueller s.n.*, Sep 1860 (MEL); Torrington SRA, 1 km E of Blather Arm / Silent Grove road junction, *Nano & Copeland 58*, 21 Feb 1997 (NE); Minyon via Mullumbimby, *White 10510*, 26 Aug 1936 (BRI); W side of Gins Mt., Mt Kaputar National Park, *Harden s.n.* (NE 33201), 9 Nov 1976 (NE); 12 km WNW along Culoul Range Rd off Windsor-Singleton Rd, *Coveny & Hind 9083*, 5 Dec 1976 (NSW); Nullica State Forest, Nethercote Waterfalls. *Albrecht 978*, 26 Sep 1984 (MEL); Jingera Rock, Egan Peak, 8 km SSE of Wyndham, *Telford 3601*, 29 Oct 1973 (CANB); Valla Beach, N of Nambucca Heads, *Williams s.n.* (NE030518A) (BRI, CANB, NE, NSW, PERTH).VICTORIA: W of Genoa Peak Road on Roger Track, *Humphries & Earl, s.n.*,(no known database number), 13 Jan 1989 (MEL).

Distribution: *Commersonia breviseta* is widespread in eastern Australia ranging from Giraween National Park in far southern Queensland to Genoa in far north-eastern Victoria. Most populations occur along the Great Dividing Range although some herbarium collections are from coastal areas at lower elevations. (Fig. 4.)

Habitat and ecology: *Commersonia breviseta* occurs in rocky areas with shallow soils on a wide range of lithologies. Parent rock types include granite, acid-volcanics, rhyolite, metasediments and sandstone. Altitudes range from near sea-level to over 1150 m. The associated plant species vary greatly across its range while the vegetation communities are usually types of heath or shrubby woodland.

Commersonia breviseta appears to be an obligate seeder that is killed by fire but germinates in abundance shortly thereafter. At a population in Washpool National Park, north-eastern N.S.W., most adult plants appeared to be killed by a wildfire in January 2003 but approximately 100 young individuals were observed flowering in September of that same year. Observations of the population near Torrington also indicate that the species reaches maturity quickly after fire then senesces within five years.

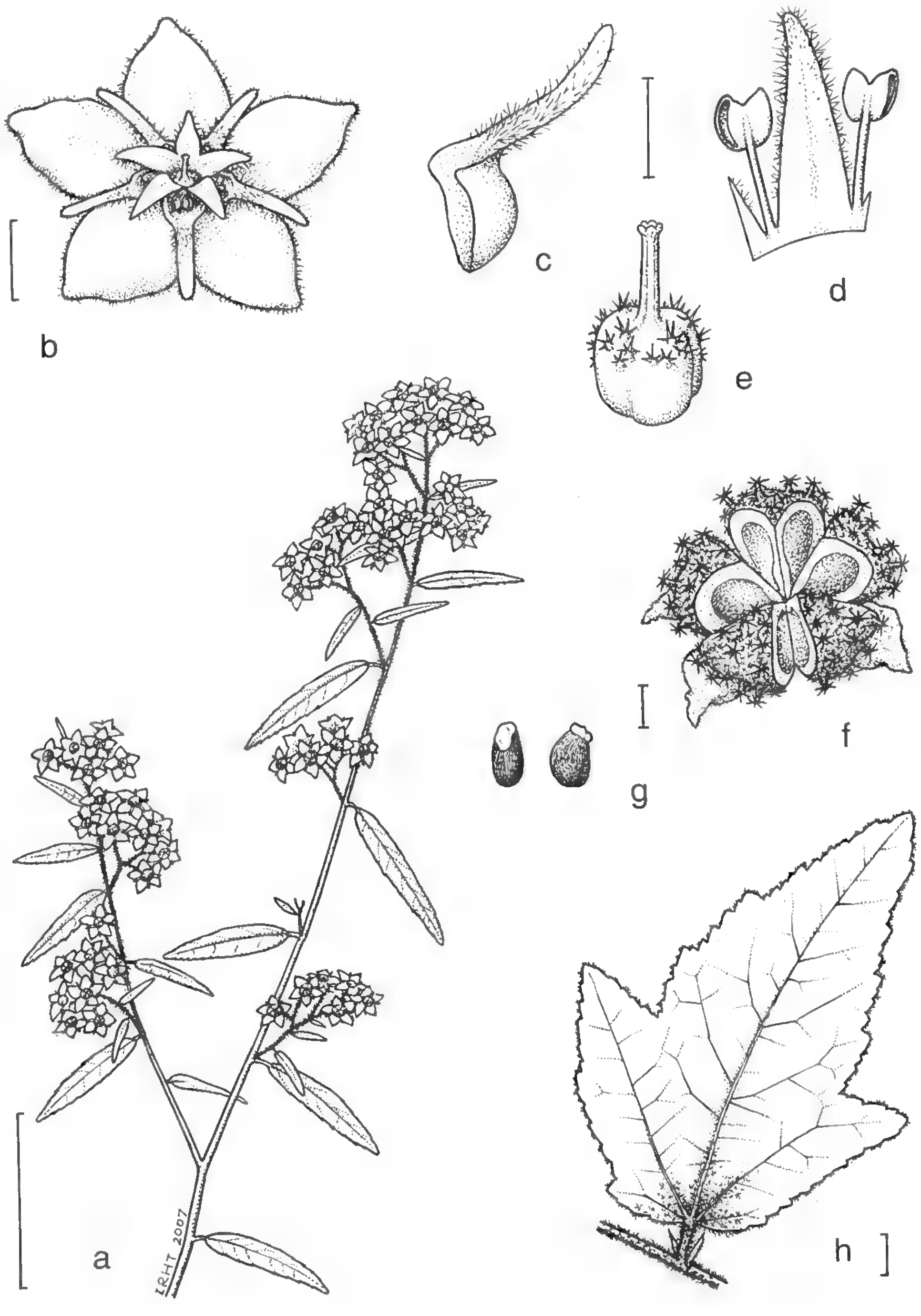

Fig. 3. *Commersonia breviseta*. **a,** habit showing flowering branchlet; **b,** flower; **c,** petal with slightly gibbous base; **d,** stamens and staminode; **e,** gynoecium; **f,** fruit with seed shed; **g,** seed; **h,** juvenile leaf. (a from type collection, *Wilkins 2053*; b–e from *Clarke NE 81918*; f, g from *Copeland 3893*; h from *Wilkins 2060*). Scale bars: a = 5 cm; b = 2 mm; c - g = 1 mm; h = 1 cm.

Phenology: flowers have been observed from September to November.

Conservation status: *Commersonia breviseta* has been widely collected since Mueller's first collection in 1860 at Yowaka River. It is widespread in eastern New South Wales, but is known from single, small populations in Queensland and Victoria. It occurs in numerous reserved areas such as Girraween, Washpool, Gibraltar Range, New England, Mt Kaputar and Deua National Parks as well as Torrington State Conservation Area. In most populations the total number of plants is relatively low, however, this species is not considered to be under threat at this time.

Etymology: the specific epithet *breviseta* is from the latin (*brevis* = short, *seta* = bristle) and refers to the short setae present on the outer surface of the fruit.

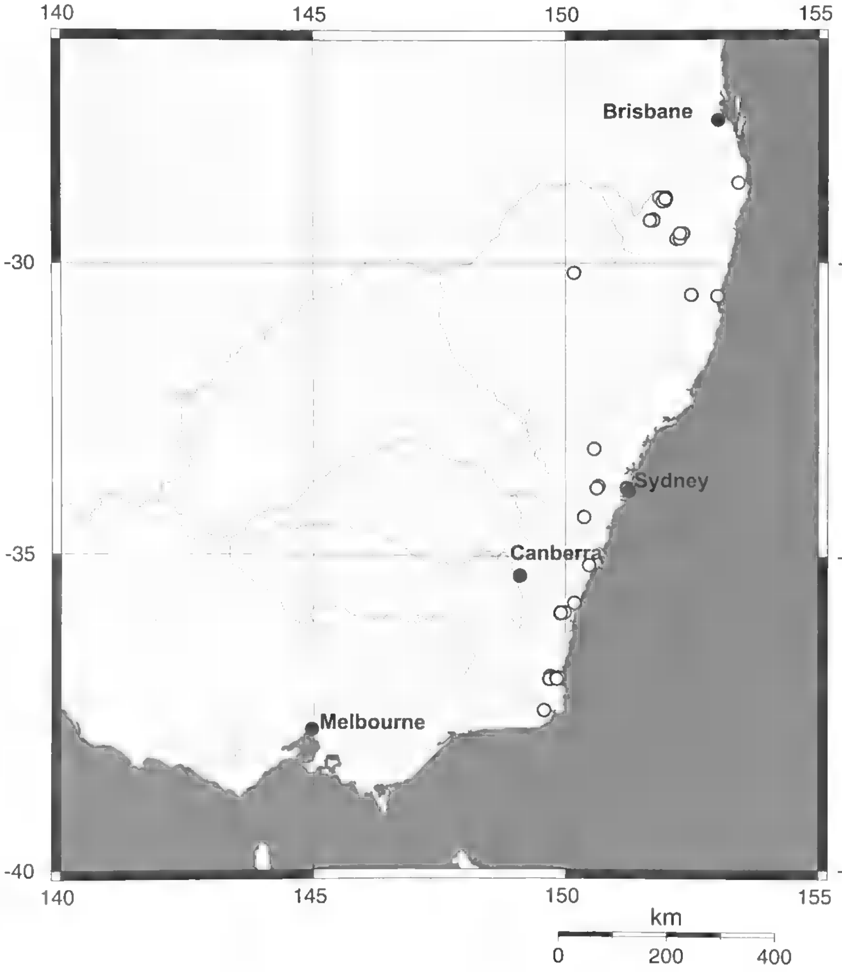

Fig. 4. Distribution of *Commersonia breviseta.*

Comparison with similar species: *Commersonia breviseta* is similar to *Rulingia hermanniifolia* in having small fruits with short setae to 0.9 mm long, the shaft of which has few hairs or glands. It differs in having a few setae mainly towards the apex of the fruit, rather than dense setae all over the surface, and differs in having leaves that are flexible rather than chartaceous. *Commersonia breviseta* is also a taller, more erect shrub.

Comment: one flower from Washpool National Park (*C.Wilkins 2052*) has small infertile anthers at the apex of the staminodes.

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The genus *Cycas* (Cycadaceae) in China

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Abstract

The genus *Cycas* is reviewed within China. Twenty two species are enumerated, one with two subspecies, and the species are placed within an infrageneric classification previously outlined. *C. panzhihuaensis* is placed in the new Section ***Panzhihuaenses***. Lectotypes are designated for *Cycas revoluta, C. balansae* and *C. miquelii*. Distribution of all taxa is mapped, conservation status discussed and a key to species provided.

Introduction

The genus *Cycas* is the single constituent genus of the family Cycadaceae, itself the basal lineage of the living cycads or Cycadophyta (Stevenson 1992). It is also the sole living cycad group occurring in Asia. The only known fossil evidence for this genus is from the Eocene of China and Japan, and this, together with the occurrence of all major lineages in the genus in mainland Asia, supports a long-term presence and probable origin of this genus in that region (Hill 1995). *Cycas* consists of about 100 species, chiefly Indo-Chinese (about 40 species) and Australian (27 species). The genus also occurs in the Malesian region, Japan and India, extending to Micronesia and Polynesia, Madagascar and East Africa. Plants are commonly understorey shrubs in forest, woodland or savanna habitats. Twenty two species are known in China.

The present work is the outcome of ongoing studies, with a total of three field trips during the period 1996–2000. Herbarium collections held by A, B, BM, BO, E, HN, K, KNF, KUN, G, L, LAE, LE, NY, PE, P and U have been examined. All specimens cited have been examined except where stated. Terminology is as in previous papers in this series (e.g. Hill 1994), as are generic and specific concepts applied. Conventions in measurements taken and presented in the following descriptions are as in other papers in this series, and are set out in Lindstrom and Hill (2007). Nomenclature follows the latest version of the International Code of Botanical Nomenclature [ICBN] (McNeill et al. 2006).

Taxonomic History

The cycad flora of China has not been well understood in the past, as is evidenced by the history of species description. Only four of the 22 species recognised herein were described before 1975, with only one of these actually being described from Chinese material.

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The comprehensive account of the genus by de Candolle (1868) summarised work to that point, and recorded no cycad species from the region of China. Pilger (1926) recorded only *C. revoluta* and *C. taiwaniana* from China. Schuster (1932) recorded *C. siamensis* (based on *Morse 273*), *C. micholitzii* (also based on *Morse 273*) and *C. revoluta* (which included *C. taiwaniana* as a variety) as Chinese, but clearly showed little understanding of the taxonomy or geography of the species.

Cheng et al. (1975) enumerated 8 species, 7 of which they regarded as native in China. They misapplied the name *C. siamensis* to the species here treated as *C. collina*, and also confused the concept of *C. taiwainiana*, including citations of *C. taitungensis* under what was essentially the correct description for *C. taiwaniana*.

Since 1975, some 32 new species names have been coined for cycads occurring naturally in China. Many of these are herein regarded as superfluous names falling into synonymies of other species, and are listed below under the species concerned. No recent publication has fully correctly applied the available names for the Chinese cycads (Chen & Stevenson 1999, Chen & Liu 2004, Xaio et al. 2004, Xaio & Gong 2006) and this publication was seen as necessary in order to clarify nomenclatural applications in China.

Hybridism

The problem of hybridism in *Cycas* has been introduced elsewhere (Hill 1992, 1996). The lack of pollinator specificity, when combined with the apparently weak inherent fertility barriers, results in the major reproductive barrier between *Cycas* species in nature being geographic separation. Natural populations of *Cycas* species are usually widely separated geographically, and some breakdown of reproductive isolation would therefore be expected where different species have spread to within pollination range of each other.

A number of natural occurrences are postulated to be of just such hybrid origin. These are morphologically intermediate between the putative parent species and, in the cases of postulated hybrid swarms, show the high degree of variability to be expected from Mendelian segregation in second and later generations. Hybrids and hybrid or intergrading populations have been recorded from throughout the range of *Cycas*, wherever different species grow in relatively close proximity. Examples from China include intergradation between *C. bifida* and *C. multipinnata* and between *C. bifida* and *C. dolichophylla* (cited below under the first species of the pair listed). Plants in cultivation at Shenzhen Fairy Lake Botanic Garden are thought to represent hybrids between *C. bifida* and *C. diannanensis* [no voucher].

Conservation

Populations of many Asian species appear to have declined, sometimes dramatically, over the past century. However, there is no comparative data to support this impression, and evidence for the decline is largely anecdotal and circumstantial. Several causative factors for this decline can be observed in action today, however, even though quantitative data on the effects are not available. Two principal threats to cycads exist in China at present, habitat loss and selective removal of plants from the wild for trade or utilisation. Some but not all species occur in reserved areas already proclaimed, but enforcement within these areas is sometimes difficult. There is, however, a growing interest in habitat and species conservation within China, and additional reserved areas are being evaluated and declared.

Conservation status of all Chinese species is summarised in Table 1.

Taxonomic treatment

CYCAS L., Sp. Pl.: 1188 (1753). Lectotype: *C. circinalis* L.; designated by Stevenson in Jarvis et al. (1993).

Dioecious palm-like shrubs with aerial or subterranean, pachycaul, cylindrical stems clad with persistent leaf-bases. Leaves loosely pubescent when young, pinnate, spirally arranged, produced in seasonal growth flushes interspersed with cataphylls, lower leaflets often reduced to spines. Longitudinal ptyxis erect or rarely reflexed, horizontal ptyxis circinate. Leaflets with a single thick midrib and no lateral veins; stomata confined to abaxial surface in most species; individual ptyxis involute. Trichomes microscopically transparent, branched or simple. Leaves with vascular traces girdling stems, girdling traces not present in cataphylls or megasporophlls. Microsporophylls aggregated into determinate cones and bearing numerous microsporangia (pollen-sacs) on abaxial surfaces, with a simple sterile apex, which is often produced into an upturned spine; microsporangia opening by slits; pollen cymbiform, monosulcate. Seed cones closed at pollination, closed at seed set (in all Chinese species). Megasporophylls spirally arranged in an indeterminate terminal rosette with the central axis continuing vegetative growth. Ovules two to many (rarely one), marginally inserted on the stipe and directed obliquely outwards ('ascending'); sporophyll apically dilated into a pinnatifid, pectinate, toothed or entire lamina. Seeds with a yellow, orange or brown fleshy outer sarcotesta, and with or without spongy tissue beneath the inner woody sclerotesta. Endosperm haploid, derived from the female gametophyte. Embryo straight; with 2 cotyledons that are usually united at the tips and a very long, spirally twisted suspensor; seeds platyspermic; germination cryptocotylar.

About 100 species, chiefly Australian (27 species) and Indo-Chinese (about 40 species). The genus also occurs in the Malesian region, Japan and India, extending to Micronesia and Polynesia, Madagascar and East Africa. Plants are commonly understorey shrubs in forest, woodland or savanna habitats. Six sections are now recognised; four in Hill (1995), another in Lindstrom et al. (2008) and an additional one in this paper. There has been disagreement on subgeneric division (Wang 1996, de Laubenfels 1998) and, in the light of improved understanding of the genus, none of the proposed systems would appear entirely adequate (Hill 1998, Hill 2004a, Hill 2004b) Four clear groups, regarded below as sections, occur naturally in China.

Key to sections occurring in China

1 Ovules tomentose .... Section *Asiorientales*

1* Ovules glabrous

  2 Microsporangiate sporophylls soft or waxy, lacking an apical spine or with a very slender tightly appressed apiculus

    3 Microsporangiate sporophylls waxy; seeds red or orange; stomata encrypted .... Section *Panzhihuaenses*

    3* Microsporangiate sporophylls soft; seeds yellow; stomata not encrypted.................... .... Section *Stangerioides*

  2* Microsporangiate sporophylls hard, with a distinct apical spine

    4 Megasporophyll pectinate .... Section *Indosinenses*

    4* Megasporophyll entire or dentate, not deeply pectinate .... Section #*Cycas*

#Not known naturally in China, present in India, Thailand and Vietnam, not treated further in this paper

Key to species in China

1 Leaflets simple

  2 Leaves distinctly keeled (opposing leaflets inserted at less than 150° on rachis)

    3 Trunk not tomentose at apex; trunk smooth; mature leaves grey-green .... 22. *C. hongheensis*

    3* Trunk densely tomentose at apex; trunk not smooth; mature leaves dark green

      4 Leaflets with margins revolute .... 1. *C. revoluta*

      4* Leaflets with margins recurved, never revolute .... 2. *C. taitungensis*

  2* Leaves flat or openly keeled (opposing leaflets inserted at more than 150° on rachis)

    5 Microsporangiate cones soft or waxy; sarcotesta not fibrous; sclerotesta with more or less verrucose ornamentation

      6 Apical spine of megasporophyll lamina dilated, markedly different from lateral spines

        7 Plants lithophytic on exposed limestone outcrops

          8 Megasporophyll lamina 35–55 long × 30–50 mm wide ...20. *C. sexseminifera*

          8* Megasporophyll lamina 70–110 long × 50–80 mm wide... 19. *C. ferruginea*

        7* Plants growing in soil

          9 Trunks subterranean

            10 Leaflets 6–10 mm wide, twisted on rachis .... 15. *C. changjiangensis*

            10* Leaflets 9–20 mm wide, flat on rachis .... 5. *C. segmentifida*

          9* Trunks aerial

11 Male cones 50 cm long or more .... 7. *C. diannanensis*

11* Male cones less than 50 cm long

12 Sarcostesta red or orange .... 3. *C. panzhihuaensis*

12* Sarcostesta yellow

13 Petioles spinescent throughout, including across swollen petiole base

14 Leaflets 9–16 mm wide; petiole 30–60% of leaf;
trunk not swollen at base .... 12. *C. taiwaniana*

14* Leaflets 6–10 mm wide; petiole 20–30% of leaf;
trunk swollen at base .... 13. *C. hainanensis*

13* Petioles usually not spinescent throughout, especially not across swollen petiole base

15 Leaflets 8–12 mm wide, twisted on rachis .. 4. *C. guizhouensis*

15* Leaflets 9–20 mm wide, flat on rachis .... 5. *C. segmentifida*

6* Apical spine of megasporophyll lamina not dilated, similar to lateral spines

16 Microsporophyll with a distinct terminal spine.......................10. *C. tanqingii*

16* Microsporophyll lacking a terminal spine

17 Petiolar spines 4–10 mm long

18 Leaflets 10–15 mm wide, narrowed and tapered at base,
petiole long (30–40% of leaf) .... 9. *C. balansae*

18*
petiole short (20–35% of leaf) .... 6. *C. dolichophylla*

17* Petiolar spines 1–3 mm long

19 Plant arborescent

20 Petiole length greater than or equal to 50 cm ....
.... 11. *C. szechuanensis*

20* Petiole length less than 50 cm .... 14. *C. shanyaensis*

19* Plant acaulescent .... 8. *C. collina*

5* Microsporangiate cones firm; sarcotesta with a fibrous layer;
sclerotesa not ornamented .... 21. *C. pectinata*

1* Leaflets divided

21 Leaflets themselves pinnately divided

22 Leaves 1–2, to 6 m, segments obovate-linear, apex shortly acuminate
to caudate .... 17. *C. multipinnata*

22* Leaves 3–15, to 3.0 m, segments linear, apex long attenuate or
long acuminate .... 18. *C. debaoensis*

21* Leaflets dichotomously divided only .... 16. *C. bifida*

Table 1. Conservation status of Chinese cycads.

	Outside China	1997 Red List Status	Reserve	IUCN Ver 3.1 2001 (Donaldson 2003)	Pop. Size	Present Decline	Range (km^2)	Hab. Reduct. (%)
C. balansae	Vietnam	-	y	NT	>10,000	low	400	<30
C. bifida	Vietnam	E*	y	VU	>10,000	high	100	30-50
C. changjiangensis	-	-	y	EN	2000	low	20	50
C. collina	Vietnam		n	VU	2,500 -10,000	low	200	30-50
C. debaoensis	-	-	y	CR	500	high	3	50
C. diannanensis	-	-	n	VU	5000	high	300	50
C. dolichophylla	Vietnam	-	y	VU	>10,000	low	500	30-50
C. ferruginea	Vietnam	-	y	NT	>100,000	low	150	20
C. guizhouensis	-	V	y	NT	>10,000	high	500	20-50
C. hainanensis	-	V		EN	10,000	low	200	50
C. hongheensis	-	E	n	CR	100	high	5	50
C. multipinnata	Vietnam	E	y	EN	1000-2500	low	250	50
C. panzhihuaensis	-	-	y	NT	> 200,000	high	150	20-50
C. pectinata	Cambodia India Laos Nepal Thailand Vietnam	-	y	VU	> 200,000	low	3,000	30-50
C. revoluta	Japan	-	y	NT	>10,000	stable	1000	<20
C. shanyaensis		-	?	NE#	?	?	?	?
C. segmentifida	?Vietnam	-	y	VU	>10,000	low	500	30-50
C. sexseminifera	Vietnam	-	n	NT	>10,000	low	500	<20
C. szechuanensis	-	Ex	n	CR	<100	high	1	?
C. taitungensis	-	V	y	VU	10,000	low	50	30-50
C. taiwaniana	-	V	y	EN	5,000	high	400	50-80
C. tanqingii	?Vietnam	-	n	NT	>100,000	stable	100	<20

*as *C. micholitzii*

recommended status

A. Section **ASIORIENTALES** J. Schust.

Cycas section *Asiorientales* J. Schust., Pflanzenr. 99: 65 (1932).

Type: C. revoluta Thunb.

This section is defined by the firm, waxy microsporangiate cones and microsporophylls, the pectinate megasporophyll apices, the tomentose ovules, and the red seeds with a non-fibrous sarcotesta and a smooth, longitudinally grooved sclerotesta. The group is relictual, and includes only two closely related species occuring in eastern China and southern Japan (Fig. 1). Although firm and waxy as they develop, male cones and microsporophylls become soft and break down quickly afer maturity. This section shares deeply encrypted stomata with section Panzhihuaenses.

1. *Cycas revoluta* Thunb., Verh. Holl. Maatsch. Weetensch. Haarlem 20(2): 424, 426–427 (1782).

Type: (lectotype here designated) ex herb. Thunberg (UPS 23734).

Cycas miquelii Warb., Monsunia 1: 179, 181 (1900).

Epicycas miquelii (Warb.) de Laub., in De Laub. & Adema, Blumea 43: 393 (1998).

Lectotype (**here designated**): ex horto Buitenzorg (ex China & Japonic.) in H. Amstelod. introducta (U: two sheets U028127, U028129). See discussion below.

Cycas revoluta var. *brevifrons* Miq., Tijdschr. Wis-Natuurk. Wetensch. Eerste Kl. Kon. Ned. Inst. Wetensch. 1: 207 (1848).

Type: from living garden material, apparently not preserved. This and the varieties listed below apparently represent horticultural variations within *C. revoluta*, of no real taxonomic significance. They are hence included in the synonymy of this species.

Cycas revoluta var. *planifolia* Miq., Monogr. Cycad.: 25–26 (1842).

Type: Hort. Amsterdam, 1840, *Miquel s.n.* (holo U).

Cycas revoluta var. *prolifera* Siebold & Zucc., Abh. Math.-Physik. Cl. Konigl. Bayer. Akad. Wiss. 14(3): 236 (1846).

Type: from living garden material, apparently not preserved.

Cycas revoluta var. *robusta* Messeri, Nuovo Giorn. Bot. Ital., n.s., 34: 324, 327 (1927).

Type: from living garden material cultivated in Florence, apparently not preserved

Literature: Gaudichaud (1829), Merrill (1912), Merrill (1917), Merrill (1923), Leandri (1931), Ho and Duong (1960), Raizada & Sahni (1960), Smitinand (1971), Smitinand (1972), Walker (1976), Zamora and Co (1986), Wang (1996).

Illustrations: Smith (1801), Bot. Mag. (1830), Miquel (1842), Warburg (1900), Schuster (1932), Smitinand (1971), Cheng et al. (1976), Zamora and Co (1986), Wang (1996).

Etymology: from the Latin *revolutus*, rolled, from the rolled leaf margins.

Vernacular: Chinese - *tieshu* (iron tree), *feng-wei-jiao-ye* (phoenix tail banana), *su-tie*, English (hort.) - *sago palm, king sago*; Japanese (Main islands) - *sotetsu* (preferred) (coming back from the dead by iron), *hou bi* (bird's tail feathers), *hou bi shou* (broken banana leaf), *sha ka shou* (firebreak banana), *ban shou* (barbarian's banana), *tesshou, tessio* (iron banana), *tosso*; Japanese (Ryukyu Is) *hichichi, hitichi, satetsu, shichichi, sichi,* *sichidzi, sidzichi, sidzidzui, sihittu, sirichi, sitechi, sitichi, sitidzi, sitochi, sitsuchi, sitsudzu, situchi, suidzu, suchichi, susitykuki, sutachi, suticha, sutichi, sutta, sutuku, suutichi, syutta, syutto, tsudzu* (all ref. to whole plants), *kyungama, mii, nadzu, nari, sutitsi-nari, yanabu* (ref. to seeds only) (Osborne & Tomiyama 1995, Bonta & Osborne 2007).

Stems arborescent, to 1–3(–7) m tall, 20 cm diam. at narrowest point, 110–160 leaves in crown. *Leaves* deep green, semiglossy, 50–150 cm long, strongly to moderately keeled (opposing leaflets inserted at 70–120° on rachis), with 100–240 leaflets, with orange tomentum shedding as leaf expands; rachis usually terminated by a spine; petiole 6–10 cm long, (8–15% of total leaf), glabrous, spinescent for 80–100% of length; basal leaflets gradually reducing to spines, 10–20 mm long, spines 1–3 mm long. *Median leaflets* simple, strongly discolorous, 80–180 mm long, 3–6 mm wide, inserted at 30–40° to rachis, decurrent for 2–5 mm; narrowed to 2–3 mm at base (to 33–50% of maximum width), 2.5–5 mm apart on rachis; section slightly keeled; margins revolute; apex aristate, spinescent; midrib flat above, raised below. *Cataphylls* linear, pungent, densely floccose, 7–11 mm long. *Pollen cones* fusiform, yellow, 30–60 cm long, 8–16 cm diam.; microsporophyll lamina waxy, not dorsiventrally thickened, 23–28 mm long, 5.5–10 mm wide, fertile zone 24–27 mm long, sterile apex 6–8 mm long, apical spine absent; apex deflexed, 4.5–8 mm long. *Megasporophylls* 12–19 cm long, yellow-tomentose; ovules 2–6, pubescent; lamina orbicular, 50–120 mm long, 40–55 mm wide, deeply pectinate, with 13–27 soft lateral spines 20–28 mm long, 2–3 mm wide; apical spine distinct or not distinct from lateral spines, 30–50 mm long. *Seeds* ovoid, 25 mm long, 20 mm wide; sarcotesta red, slightly pruinose, 3–5 mm thick; fibrous layer absent; sclerotesta smooth, or longitudinally grooved; spongy endocarp absent.

Historical notes: *C. revoluta* was the second species of *Cycas* to be recognised, described in 1782 by Swedish botanist and physician Carl Peter Thunberg. No type was cited. The 'Tessio' of both Kaempfer (1712: V, 897) and Rumphius (1741: I,70, t.24) were included as synonyms (Thunberg 1784). Reference was also made to cultivated plants, which were probably collected by Thunberg in Japan in 1775–1776, specimens now in UPS. Of the three sheets of *C. revoluta* present in the Thunberg herbarium, the sheet indicated was chosen as lectotype because it was the only sheet annotated 'e Japonia'.

No type was cited by Warburg when he described *C. miquelii*, and distribution was cited only as "Süd-China". However, Warburg (p. 179) makes indirect reference to Miquel's mention of a plant cultivated in the Amsterdam Botanic Garden that had been brought in from the Bogor Botanic Garden and said to be from South China (Miquel 1851: 28); Miquel had incorrectly determined and illustrated these as *C. inermis*. Although not explicitly cited, these would appear to be the basis for *C. miquelii*, and hence can be considered original material under the Code (ICBN Art. 9.2 & Note 2) and acceptable as lectotypes. These specimens are clearly somewhat aberrant forms of *C. revoluta* lacking petiolar spines. *C. miquelii* must therefore fall into the synonymy of *C. revoluta*. *Cycas inermis* is a distinct species from southern Vietnam (see Hill et al. 2004). The neotypification in de Laubenfels and Adema (1998: 393) is based on a specimen of a quite different species from southern Thailand (*C. clivicola*, see also under *C. sexseminifera*). This choice is redundant when the Utrecht specimens from the Amsterdam Botanic Garden are taken as original material. It is also in conflict with the protologue in that the specimen is not from southern China.

Distinguishing features: readily distinguished by the keeled, stiff leaves with crowded, stiff, narrow leaflets with strongly recurved or revolute margins and the tomentose ovules.

Distribution and habitat: widely distributed through the Ryukyu Islands of southern Japan, today primarily on steep to precipitous stony sites, but previously on flatter land now cleared. Reports of natural occurrences in coastal Fujian Province of China have not been substantiated in recent times, although circumstantial support for these claims is strong (Fig. 1).

Conservation status: a number of natural stands are in protected areas, and this species is in cultivation worldwide in vast numbers, from artificially propagated sources. No immediate threat is evident. The Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003) but is here regarded as **LC.**

Selected specimens examined: CHINA: Fujian: near Chekiang border, 600–1200m, *Ching 2260*, Aug 1924 (BM); Diongloh Hsien, Meihwa, *Chung 2045*, 29 Jul 1923 (K). **JAPAN:** Ins. Tanegashima, Nishino-Omote, *Ohwi & Okamoto TSM 994*, 7 Nov 1953 (B, K); Liukiu Is., wild on sea cliffs around Nahe, *Wilson 8058*, 11 Mar 1917 (K, NY); Ryukyu Is., Taketomi Shima, Omasu, NE of Hazama, *Fosberg 37634*, 19 Jun 1956 (K, NY); Ryukyu Is., Myako Jina, 0.5 km SE of Matsubara, *Fosberg 38242*, 14 Aug 1956 (K, NY); Ryukyu Is., Ishigaki Shima, 0.5 km S of Todoroki Gawa, *Fosberg 38117*, 31 Jul 1956 (K); Ryukyu Is., Okinawa Hontoo, Kiyan Itoman-shi, *Myshi Furuse 2413*, 10 Nov 1972 (K); Ryukyu, Ins. Okinawa, Oku, *Tamura 25854*, 9 Oct 1972 (B).

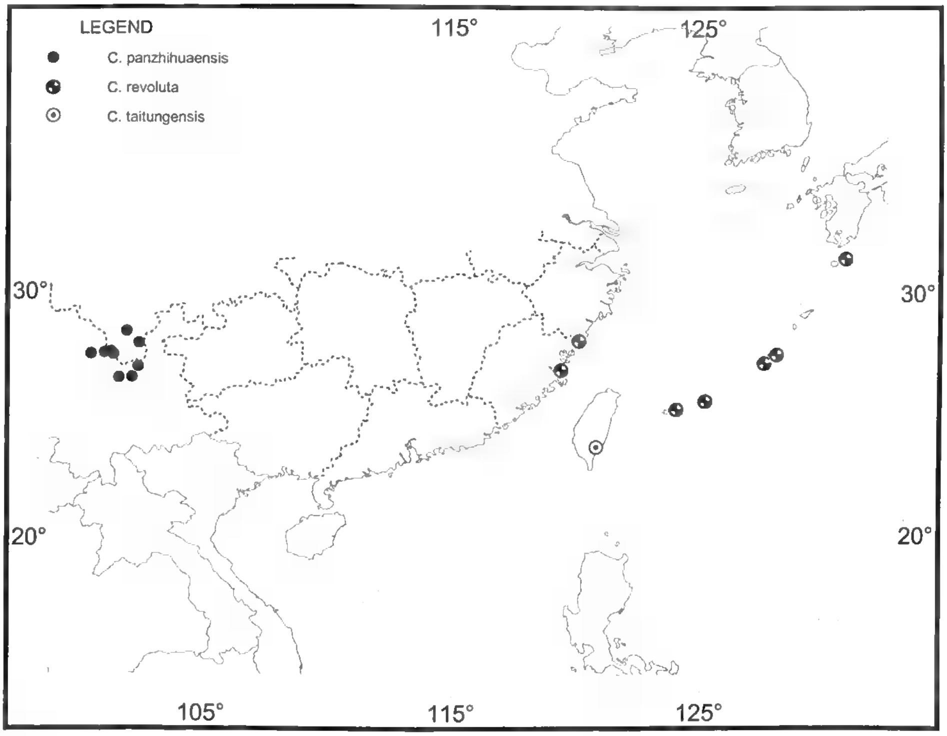

Fig. 1. Distributions of *C. panzhihuaensis, C. revoluta, C. taitungensis.*

2. ***Cycas taitungensis*** C.F.Shen, K.D.Hill, C.H.Tsou & C.J.Chen, Bot. Bull. Acad. Sin. 35: 135–138 (1994).

Type: Taiwan, Taitung Hsien, Yenping, in the Cycad Reserve, *Chi-Hua Tsou 825*, 28 Jun 1993 (holo HAST; iso A, BM, K, NSW, NY, P, PE, TAI).

Literature: Li (1980), Wang (1996).

Illustrations: Cheng et al. (1975), Li (1980), Wang (1996).

Etymology: from the prefecture of Taitung, a mountainous region in south-eastern Taiwan, where this species is native, with the Latin termination -ensis, place of origin.

Vernacular: Chinese - *tai-dong su-tie*, *feng-wei-jiao* (Phoenix-tail grass or palm); English (hort.) - *emperor sago* (Chen et al. 1995, Bonta & Osborne 2007).

Stems arborescent, to 3(–6) m tall, 25–30 cm diam. at narrowest point. *Leaves* deep green, semiglossy, 100–180 cm long, moderately keeled (opposing leaflets inserted at 120–150° on rachis), with 150–170 leaflets, with orange tomentum shedding as leaf expands; rachis usually terminated by a spine; petiole 15–20 cm long (15–20% of total leaf), petiole glabrous, spinescent for 50–90% of length; basal leaflets gradually reducing to spines, c. 30 mm long, spines 1–3 mm long. *Median leaflets* simple, strongly discolorous, 120–170 mm long, 6–8 mm wide, inserted at 45–60° to rachis, decurrent for 2.5–4.5 mm, narrowed to 2–2.5 mm at base (to 30–45% of maximum width), 4.5–6 mm apart on rachis; section slightly keeled; margins recurved; apex acute, spinescent; midrib flat above, raised below. *Cataphylls* linear, pungent, densely floccose, 7–11 mm long. *Pollen cones* fusiform, yellow, 35–50 cm long, 8.5–10 cm diam.; microsporophyll lamina waxy, not dorsiventrally thickened, 35–40 mm long, 11.5–15 mm wide, fertile zone 25–30 mm long, sterile apex 4.5–10 mm long, apical spine absent; apex deflexed, 6 mm long. *Megasporophylls* 21–26 cm long, brown-tomentose; ovules 2–6, pubescent; lamina orbicular, 100–130 mm long, 80–100 mm wide, deeply pectinate, with 28–36 soft lateral spines 35–45 mm long, 1.5–3 mm wide, apical spine not distinct from lateral spines. *Seeds* oblong, 40–45 mm long, 25–30 mm wide; sarcotesta red, slightly pruinose, 1.5–3 mm thick; fibrous layer absent; sclerotesta longitudinally grooved; spongy endocarp absent.

Historical notes: although not described until 1994, this species was widely known previously under the misapplied name *C. taiwaniana*.

Distinguishing features: although very close to *C. revoluta*, this species is readily distinguished by the longer, flatter leaves with longer and flatter leaflets. Female cones also tend to be more tightly imbricate and cabbage-like, and seeds are darker in colour.

Distribution and habitat: known only from the mountainous southern parts of Taiwan, growing on steep to precipitous slopes (Fig. 1).

Conservation status: although a stand occurs in a nature reserve established specifically for this cycad, the area is small and subject to earth movement and erosion. Ver 3.1:IUCN (2001) status is **VU** (Donaldson 2003).

Selected specimens examined: CHINA: Taiwan: Taitung County, inter Sesui et Matuyama, *Yamamoto & Goto*, 28 Dec 1928 (TAI 194156, TAI 194157, TAI 194159); Taitung, *Hsieh & Tsou s.n.*, Nov 1992 (PE). **Cult.:** Burpengary, Queensland, Australia, from seed from Taitung, Taiwan, *Walkley NSW 265951*, Feb 1993 (NSW); Ningyang, Fujian, China, from Taitung, Taiwan, *Lin 5562* (PE); Xianhe Bot. Gard., Shenzen, China, from Taitung, Taiwan, *Chen 92589* (PE); Kaede Taito-cho, *Tanaka 10451*, 7 Mar 1931 (BM, NY).

B. Section **PANZHIHUAENSES** (D.Yue Wang) K.D.Hill, stat. nov.

Cycas subgenus *Panzhihuaenses* D.Yue Wang, Cycads China 26 (1996).

Type: *C. panzhihuaensis* L.Zhou & S.Y.Yang

This section is defined by the firm, waxy microsporangiate cones and microsporophylls, the pectinate megasporophyll apices, the glabrous ovules, and the red to orange seeds with a non-fibrous sarcotesta and a smooth, unornamented sclerotesta. The circumscription as applied here includes only the type species, in contrast to the circumscription of Wang (1996). The group is relictual, and includes only a single species occuring in south-western China (Fig. 1). Although firm and waxy as developing, male cones and microsporophylls become soft and break down quickly afer maturity. This section shares deeply encrypted stomata with section *Asiorientales*.

3. *Cycas panzhihuaensis* L.Zhou & S.Y.Yang, Acta Phytotax. Sin. 19(3): 335, Tab. 10, Fig. 1–6; Tab. 11, Fig. 1–10 (1981).

Type: China, Sichuan, Dukou, Baguan He, Yang Siyuan 10 (holo PE).

Cycas baguanheensis L.K.Fu & S.Z.Cheng, Acta Phytotax. Sin. 19(3): 337 (1981).

Type: China, Sichuan, Dukow Shi (Panzihua City), Yang Si-Yuan & Wu Bin 13, 1979 (holo PE). Included in *C. panzhihuaensis* by Zhou and Yang (1981).

Literature: Wang (1996).

Illustrations: Wang (1996).

Etymology: from the natural occurrence of this species in the Panzihua Prefecture of southern Sichuan Province, China, with the Latin termination *-ensis*, place of origin.

Vernacular: Chinese - *e-bao-gong, e-boa-chi, Panzhihua su-tie* (Walters & Yang 1994, Bonta & Osborne 2007).

Stems arborescent, to 1–2(–3) m tall, 15–20 cm diam. at narrowest point; 30–80 leaves in crown. *Leaves* bluish, semiglossy, 70–150 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis), with 140–250 leaflets, with orange tomentum persistent below; rachis consistently terminated by paired leaflets; petiole 7–25 cm long (15–25% of total leaf), petiole glabrous, spinescent for 50–70% of length; basal leaflets not gradually reducing to spines, 50–70 mm long, spines 1–3 mm long. *Median leaflets* simple, strongly discolorous, 120–230 mm long, 5–7 mm wide, inserted at 50–60° to rachis, decurrent for 4–6 mm, narrowed to 2–3 mm at base (to 35–45% of maximum width), 6–10 mm apart on rachis; section flat; margins flat to slightly recurved; apex aristate, spinescent; midrib flat above, raised below. *Cataphylls* narrowly triangular, soft, densely brown floccose, 60–90 mm long. *Pollen cones* fusiform, yellow, 25–50 cm long, 8–14 cm diam.; microsporophyll lamina waxy, not dorsiventrally thickened, 40–60 mm long, 18–32 mm wide, fertile zone 30–40 mm long, sterile apex 8–11 mm long, deflexed; apical spine rudimentary, deflexed, 1–4 mm long. *Megasporophylls* 11–21 cm long, yellow-tomentose or brown-tomentose; ovules 1–5, glabrous; lamina orbicular, 70–150 mm long, 35–70 mm wide, deeply pectinate, with 23–40 soft lateral spines 10–40 mm long, 2–2.5 mm wide, apical spine not distinct from lateral spines. *Seeds* subglobose, 25–35 mm long, 22–30 mm wide; sarcotesta red to orange, not pruinose, 1.5 mm thick; fibrous layer absent; sclerotesta smooth; spongy endocarp absent.

Historical notes: probably the most abundant Chinese cycad, although only recently described. This species was named in 1981 by Chinese horticulturists Lin Zhou and Si-Yuan Yang, based on specimens that Yang and Bin Wu had collected near Dukou, now Panzhihua City, in 1979. In the same paper, Chinese botanists Li-Kuo Fu and Shu-Zhi Cheng from the Institute of Botany in Beijing described *C. baguanheensis*, based on collections by Yang and Wu from Baguan He, also near Panzhihua City, collected on the same expedition in 1979. It has been generally accepted subsequently, however, that the latter was merely a depauperate form of the former from a harsher site (Guan 1983, Zhou 1990).

Distinguishing features: one of the most distinct of the Chinese cycads, characterised by the flat, erect leaves with narrow, dull bluish leaflets and the small, orange-red seeds.

Distribution and habitat: known from southern Sichuan and northern Yunnan Provinces (Fig. 1), typically in fairly dry, closed low woodland or shrubland thickets on moderately to steeply sloping sites. Soil is usually derived from limestone, although occurrences on shale and sandstone are known. As with all mainland Asian cycads, human population pressure has had considerable impact, and present distributions may represent a small fraction of the distribution of only a century ago.

Conservation status: although populations numbering hundreds of thousands were recently recorded (Zhou 1990), and two nature reserves have been designated for the protection of this species, it must still be regarded as potentially endangered. Much of the habitat is under immediate threat of clear cutting for fuel and agricultural land, and plants are being extensively collected for sale as food, medicine and ornamentals, even within the reserves (Walters et al. 1995). Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003).

Selected specimens examined: CHINA: Yunnan: Yan Mou, Longjie, *Wu 840103*, May 1984 (KUN); Lu Quan county, *Li 03* (KNF).

C. Section **STANGERIOIDES** Smitinand

Cycas section *Stangerioides* Smitinand, Nat. Hist. Bull. Siam. Soc. 24: 168 (1971). Type: *C. micholitzii* Dyer.

This section is defined by the soft microsporangiate cones and microsporophylls, the pectinate megasporophyll apices, the glabrous ovules, and the yellow seeds with a non-fibrous, loose, freely peeling sarcotesta, and a verrucose sclerotesta. It is a taxonomically complex group, circumscribed as by Hill (1995), rather than Smitinand (1971) or Wang (1996), although present knowledge would also suggest exclusion of the Chinese species *C. panzhihuaensis* from the section. The group encompasses most of the Chinese species, and ranges from northern Thailand and north-eastern Myanmar east through Laos, Vietnam and southern China. Seventeen species occur in China, in the south and east (Figs. 2–5).

4. *Cycas guizhouensis* Lan & R.F.Zou, Acta Phytotax. Sin. 21(2): 5 (1983).

Type: China, Guizhou: cultivated in hospital of Xingyi (plants originally introduced from Wantun, Xingyi), 10 Aug 1981, *K.M. Lan et R.F. Zou 81–8–0001* (holotype in Herb. Guizhou Agr. Coll; iso PE).

Cycas multiovula D.Y.Wang, Cycads China: 83 (1996).

Type: cultivated in Gejiu, Yunnan, China, *D.Y. Wang 5574* (holo SZG; isotypes IBSC, NF).

Literature: Wang (1996).

Illustrations: Wang (1996).

Etymology: from Guizhou province, with the Latin termination -ensis, place of origin.

Vernacular: Chinese - *feng-wei-cao* (Phoenix-tail grass or palm), *feng-wie-tie, feng-wei su-tie, Guizhou su-tie, Nanpan jiang su-tie* (Nanpan River cycad), (qiannian), *guan-yin-lian, shan-bo-lou, su-tie* (Walters & Yang 1994, Bonta & Osborne 2007).

Stems arborescent to acaulescent, to 1 m tall, 10–15 cm diam. at narrowest point; 5–20 leaves in crown. *Leaves* deep green, semiglossy, 100–180 cm long, slightly keeled (opposing leaflets inserted at 130–170° on rachis), with 110–210 leaflets, with orange tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 30–60 cm long (25–40% of total leaf), petiole glabrous, spinescent for 40–100% of length but not spinescent across swollen base; basal leaflets not gradually reducing to spines, 110–200 mm long; spines 1–4 mm long. *Median leaflets* simple, strongly discolorous, 160–370 mm long, 8–12 mm wide, inserted at 55–65° to rachis, decurrent for 4–5 mm, narrowed to 2.5–3 mm at base (to 30–40% of maximum width), 10–16 mm apart on rachis, somewhat twisted (insertion not parallel to rachis); section slightly keeled; margins flat, or slightly recurved; apex acute, not spinescent; midrib raised above, flat below or raised below. *Cataphylls* narrowly triangular, soft, pilose, 50–80 mm long. *Pollen cones* fusiform, orange to brown (very pale), 20–40 cm long, 6–14 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 30–40 mm long, 17–20 mm wide, fertile zone 27–36 mm long, sterile apex 3–5 mm long, level, apical spine absent. *Megasporophylls* 10–20 cm long, yellow-tomentose or brown-tomentose; ovules 4–8, glabrous; lamina orbicular, 60–70 mm long, 60–80 mm wide, deeply pectinate, with 17–33 soft lateral spines 20–45 mm long, 2–4 mm wide, apical spine distinct from lateral spines, 25–45 mm long, 9–17 mm wide at base. *Seeds* subglobose, 23–29 mm long, 22–28 mm wide; sarcotesta yellow, not pruinose, 1.5 mm thick; fibrous layer absent; sclerotesta smooth or verrucose; spongy endocarp absent.

Historical notes: when described in 1983 by Chinese botanists K.M. Lan and R.F. Zou, this species was contrasted with *C. pectinata*, although its affinities are actually with the group of Chinese cycads that includes *C. balansae* and *C. taiwaniana*. The type was collected by Lan and Zou from a cultivated plant in the grounds of the Xingyi hospital in 1981, although wild collections were also known. The type of *C. multiovula* was later collected from the same place.

Distinguishing features: within the group of Chinese cycads with soft pollen cones, loose, freely peeling sarcotesta lacking a fibrous layer and verrucose sculpting of the sclerotesta (Section *Stangerioides*), this species is distinguished by the narrow leaflets and small stature, with a petiole that is usually not wholly spinescent, and leaves that are slightly keeled with leaflets distinctly twisted on the rachis. Pollen cones are also quite large (to 40 cm long).

Distribution and habitat: this species is known from the Nanpan and Qingshui valleys in south-western Guizhou province, eastern Yunnan and north-western Guangxi provinces (Fig. 2). It is typical of low, scrubby forests on steep slopes on limestone bluffs or screes.

Conservation status: Walters et al. (1995) report extensive destruction of this species during the cultural revolution, regarding it as the most seriously threatened of all Chinese cycads. They also report that the Qian-Xu-Nan Prefecture Department of Forestry in Xing-yi has abandoned hope of in situ protection (in that prefecture), and are concentrating on ex situ conservation collections. More recent studies indicate however that this species is moderately abundant over a considerable area around the common borders of Guizhou, Guangxi and Yunnan provincesIt is listed by the 1997 IUCN Red List of Threatened Plants as category V, although considerable confusion is shown by the inclusion of *C. szechuanensis* as a synonym, and then the listing of the latter separately as category Ex (see also *C. szechuanensis*). Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003).

Selected specimens examined: CHINA: Guangxi: cultivated in Longlin city, Collected nearby, *C.J. Chen, Y.C. Zhong & K.D. Hill 24, 25*, 15 Nov 1998 (NSW, FTG HN, NY, PE); cultivated in Xingyi city, Collected nearby, *C.J. Chen, Y.C. Zhong & K.D. Hill 27*, 16 Nov 1998 (NSW, HN, L NY, PE); Long Xui Ten locality, Gao Feng village, Ya Zha town, N of Longlin city, *C.J. Chen, Y.C. Zhong & K.D. Hill 26*, 16 Nov 1998 (NSW, HN, K NY, PE).

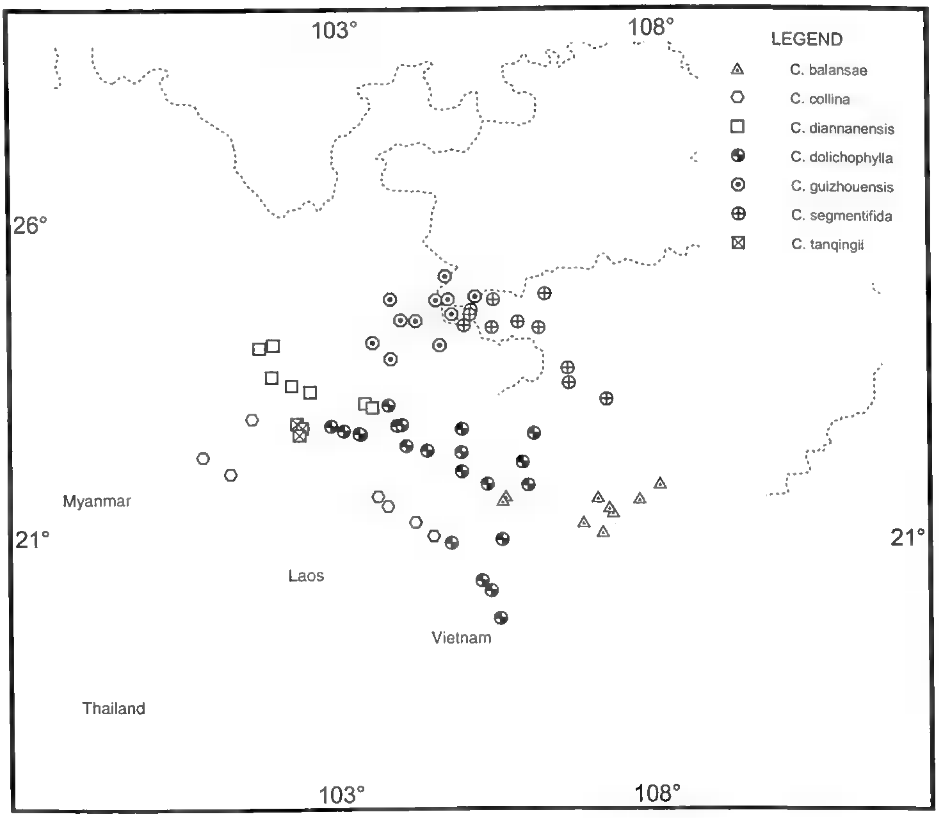

Fig. 2. Distributions of *C. balansae, C. collina, C. diannanensis, C. dolichophylla, C. guizhouensis, C. segmentifida* and *C. tanqingii.*

5. *Cycas segmentifida* D.Y.Wang & C.Y.Deng, Encephalartos 43: 11 (1995).

Type: cultivated, South China Botanical Garden, Guangzhou, China, *D.Y. Wang & H. Peng 2967*, 16 May 1994 (holo SZG; iso FTG n.v., GZAC n.v., NF n.v., NSW, XIN n.v.).

Cycas longiconifera Hung T.Chang, Y.C.Zhong & Y.Yuan Huang, *Acta Sci. Nat. Univ. Sunyatseni* 37(4): 6 (1998).

Type: China, Guangxi, Baise, alt. 850 m, in calceo-saxo, *Y.C. Zhong 8771*, 26 Mar 1998 (holo SYS). Included in the synonymy of *C. segmentifida* by Chen and Stevenson (1999).

Cycas longlinensis Hung T.Chang & Y.C.Zhong, Acta Sci. Nat. Univ. Sunyatseni 36: 68 (1997).

Type: China, Guangxi, Longlin, Mt Jin Zhong Shan, alt. 860 m, in arenoso-saxum, *Y.C. Zhong 80848*, 14 Dec 1991 (holo SYS). Included in the synonymy of *C. segmentifida* by Chen and Stevenson (1999).

Cycas multifida Hung T.Chang & Y.C.Zhong, *Acta Sci. Nat. Univ. Sunyatseni* 36: 70 (1997).

Type: China, Guanxi, Xiling, in arenoa-saxa, alt. 780 m, *Y.C. Zhong 80196*, 27 Jun 1995 (holo SYS). Included in the synonymy of *C. segmentifida* by Chen and Stevenson (1999).

Cycas xilingensis Hung T.Chang & Y.C.Zhong, *Acta Sci. Nat. Univ. Sunyatseni* 36: 69 (1997).

Type: China, Guanxi, Xiling, alt. 880 m, *Y.C. Zhong 80866*, 18 Jul 1994 (holo SYS). Included in the synonymy of *C. segmentifida* by Chen and Stevenson (1999).

Literature: Chen and Stevenson (1999), Chen and Liu (2004).

Illustrations: Wang (1996).

Etymology: from the Latin, *segmentifida*, divided into segments, from the deeply divided megasporophyll.

Stems acaulescent or arborecent, to 0.5 m tall, 10–23 cm diam. at narrowest point, 8–25 leaves in crown. *Leaves* deep green, highly glossy, 120–280 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis), with 80–190 leaflets, with orange tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 40–140 cm long (30–50% of total leaf), glabrous, spinescent for 90–100% of length; basal leaflets not gradually reducing to spines, 70–290 mm long; spines 1–4 mm long. *Median leaflets* simple, strongly discolorous, 120–420 mm long, 9–20 mm wide, inserted at 50–80° to rachis, decurrent for 4–7 mm, narrowed to 3–7 mm at base (to 30–50% of maximum width), 11–24 mm apart on rachis, inserted parallel to rachis; section flat; margins flat, sometimes undulate; apex acute, not spinescent; midrib raised above, raised below. *Cataphylls* narrowly triangular, soft, pilose, 70–100 mm long. *Pollen cones* fusiform, yellow, 30–60 cm long, 5–12 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 20–30 mm long, 15–18 mm wide, fertile zone 17–27 mm long, sterile apex 3 mm long, level, apical spine absent. *Megasporophylls* 16–25 cm long, yellow-tomentose or brown-tomentose; ovules 4–8, glabrous; lamina orbicular, 80–130 mm long, 50–120 mm wide, deeply pectinate, with 16–44 soft lateral spines 20–70 mm long, 2–3 mm wide, apical spine distinct from lateral spines, 25–125 mm long, 8–20 mm wide at base. *Seeds* subglobose, 28–35 mm long, 24–30 mm wide; sarcotesta yellow, not pruinose, 1.5 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: reports of an unidentified species from Longlin county in north-western Guangxi (Symes 1991) probably refer to this species.

Distinguishing features: within the group of Chinese cycads with soft microsporangiate cones, loose, freely peeling sarcotesta lacking a fibrous layer and verrucose sculpting of the sclerotesta (Section *Stangerioides*), this species is distinguished by the small seeds, broad leaflets with flat or undulate margins, leaflets that are flat and not twisted on the rachis, and a large megasporophyll apex with a broad apical spine.

Distribution and habitat: once an extremely widespread species through western Guangxi, extending into southern Guizhou and eastern Yunnan, in both cases to a limited extent (Fig. 2). This species occurs on a range of substrates from limestone to shale and schist, usually on steep slopes lower in valleys with some although often skeletal soil cover. Vegetation ranges from closed evergreen forest to mixed deciduous and evergreen woodland, although today is mostly severely degraded to grassland or scrubby secondary regrowth.

Conservation status: this species was moderately abundant over a considerable area in western Guangxi province, but now severely depleted. Ver 3.1:IUCN (2001) status is **VU** (Donaldson 2003).

Selected specimens examined: CHINA: Guangxi: Debao County, Ba Gen village, 5 km from Debao city, *Chen, Zhong & Hill 07*, 9 Nov 1998 (BKF, HN, K, NY, P, PE); Debao County, side road from main Debao to Baise road, *Chen, Zhong & Hill 09*, 10, 9 Nov 1998 (NSW, PE); Tianlin County, Yan Ron locality, Wei Hua village, Le Li town, 10 km SW of Tianlin city, *Chen, Zhong & Hill 11, 12*, 10 Nov 1998 (NSW, PE); Tianlin County, Fu Da town, S of Tian Lin city, cultivated in town, collected from nearby, *Chen, Zhong & Hill 15*, 11 Nov 1998 (NSW, PE); Xilin County, Long Lo Tun locality, Po Ning village, Ba Da town, ca 3 km SE of Xilin city, type locality for *C. xilingensis, Chen, Zhong & Hill 17*, 12 Nov 1998 (NSW, PE); Xilin County, Zhou Bong village, ca 9 km NE of Xilin city, type plant of *C. multifida, Chen, Zhong & Hill 18*, 12 Nov 1998 (NSW, PE); Xilin County, Zu Be town, ca 3 km SE of Xilin city, *Chen, Zhong & Hill 19*, 13 Nov 1998 (NSW, PE); Longlin County, Liu Long Guo, near Bian Ya town, E of Longlin city, *Chen, Zhong & Hill 20*, 15 Nov 1998 (NSW, PE). **Yunnan:** cult. in Funing Middle Vocational School garden, plants coll. from wild near Bo'ai, *Chen, Hong, Hill & Stevenson 001(Hong 327)*, 2 Jul 2000 (PE, YAF, IBSC, NSW, NY); cult. in Wenshan Forestry Office, plants coll. from wild at Ake, Guangnan County , *Chen, Hong ,Hill & Stevenson 002 (Hong 328)*, 3 Jul 2000 (PE, YAF, IBSC, NSW, NY).

6. *Cycas dolichophylla* K.D.Hill, H.T.Nguyen & L.K.Phan, Bot. Rev. 70(2): 157–160, fig. 7 (2004).

Type: Vietnam: Tuyen Quang: Na Hang, Pu La mountain, 2 Nov 1996, *H.T. Nguyen 2124* (holo HN)

Etymology: from the Greek *dolichos*, long, and *phyllon*, leaf, referring to the long leaves.

Stems arborescent, to 1.5 m tall, 18–30 cm diam. at narrowest point. 8–40 leaves in crown. *Leaves* bright green to deep green, highly glossy, 200–450 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis), with 150–270 leaflets, with orange tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 40–110 cm long (20–35% of total leaf), glabrous, spinescent for 90–100% of length; basal leaflets not gradually reducing to spines, 90–240 mm long; spines 4–10 mm long. *Median leaflets* simple, strongly discolorous, 190–420 mm long, 14–25 mm wide, inserted at 60–85° to rachis, decurrent for 5–8 mm, narrowed to 3–6 mm at base (to 20–35% of maximum width), distinctively rounded at base, 16–30 mm apart on rachis, inserted parallel to rachis; section flat; margins undulate; apex softly acuminate, not spinescent; midrib raised above, flat below. *Cataphylls* narrowly triangular, soft, pilose, 80–120 mm long. *Pollen cones* narrowly ovoid or fusiform, yellow, 35–58 cm long, 8–10 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 30–36 mm long, 9–13 mm wide, fertile zone 27–34 mm long, sterile apex 2–4 mm long, level; apical spine rudimentary or absent, sharply upturned, 0–3 mm long. *Megasporophylls* 15–26 cm long, brown-tomentose; ovules 2–4, glabrous; lamina orbicular, 60–120 mm long, 50–100 mm wide, deeply pectinate, with 16–26 soft spines 40–50 mm long, 2–3 mm wide, apical spine not distinct from lateral spines. *Seeds* ovoid or flattened-ovoid or oblong, 40–64 mm long, 33–36 mm wide; sarcotesta yellow, not pruinose, 2–4 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: although the most widespread and abundant cycad in northern Vietnam, *C. dolichophylla* was recognised as a distinct species only in the late 1990's.

Distinguishing features: the robust though usually short aerial trunk, the longer and more numerous leaves with more numerous leaflets that are short, broad and distinctively rounded at the base, the long slender petiolar spines and the larger microsporangiate cones with rounded microsporophylls that lack any apiculus distinguish this species. Megasporophylls are similar to those of *C. balansae*, but larger and more robust. *C. dolichophylla* is also part of the complex of closely related taxa that is distributed through northern Vietnam, Laos, northern Thailand and Yunnan and Guangxi in southern China (Section *Stangerioides*). Within this section, a subgroup that may be a natural group is defined by a robust habit with a stout erect aerial trunk. This subgroup is mainly Chinese (including *C. hainanensis, C. taiwaniana* and *C. diannanensis*), with *C. dolichophylla* the only member of the group known to extend beyond China.

Distribution and habitat: locally frequent in more sheltered sites in deep shade in tall closed evergreen forests, from near the Chinese border in the north and north-west to Ben En National Park in Thanh Hoa province in the south, extending north-west to a very short way into eastern Yunnan province (Fig. 2). This species occurs on loamy soils over limestone, shale, schist or granite, in closed evergreen forests, although today these are often reduced to scrubby regrowth and bamboo scrub.

A population occurring west of the city of Moc Chau in Vietnam has narrow leaflets with slender bases, short to medium petioles and small seeds, and is interpreted as a zone of intergradation with *C. collina*, which is abundant in higher country to the west (specimens cited under *C. collina*). Plants observed in cultivation around Vo Nhai and Yen Son districts, Thai Nguyen Province, Vietnam, were intermediate in form between *C. dolichophylla* and *C. ferruginea*, and have been interpreted as hybrid individuals. In this region, *C. ferruginea* is abundant on steep exposed limestone faces, and *C. dolichophylla* is abundant in adjacent closed forests on deep heavy soils (specimens cited below). Plants observed in cultivation in villages west of Thai Nguyen, Vietnam, and said to have been collected locally were morphologically intermediate between *C. dolichophylla* and *C. bifida*

Conservation status: Ver 3.1:IUCN (2001) status is **VU** (Donaldson 2003).

Selected specimens examined: CHINA: Yunnan: Hekou county, Anjiahe district, cult. in Machang village, plants coll. from wild at Yang Hui village, *Chen, Hong, Hill & Stevenson 003 (Hong 329),* 4 Jul 2000 (PE, YAF, IBSC, NSW, NY);Hekou county, Nanxi town, Xiaonanxihe, at 132 km of the highway, Batou , *Chen, Hong, Hill & Stevenson 004, 005 (Hong 332, 333),* 4 Jul 2000 (PE, YAF, IBSC, NSW, NY); Pingbian County, Daoyao, Mutihe village, by Jingchang River, a tributary of Nanxi River, *Chen, Hong, Hill & Stevenson 007 (Hong 345),* 5 Jul 2000 (PE, YAF, NSW, NY). **VIETNAM: Bac Can:** Bac Can city, cult., coll. from ca 13 km to SE, 15 Mar 1999, *Hill 5036 & Loc* (HN, NSW); Cho Moi, Tan Son, Nam Dat, ca 400 m. alt., 16 Mar 1999, *Hill 5037, 5038 & Loc* (HN, NSW). **Cao Bang:** Nguyen Binh, Huo Tham, Be Nuoc, ca 400 m. alt., 14 Mar 1999, *Hill 5032 & Loc* (HN, NSW). **Ha Giang:** Vi Xuyen, Viet Lam, Muc, 28 km S of Ha Giang city, cult. in village, coll. ca 3 km to NW, 26 Mar 1999, *Hill 5068 & Loc* (HN, NSW); Vinh Tuy, SE edge of Vinh Tuy townlet, cult. in garden, coll. ca 20 km SW, 26 Mar 1999, *Hill 5069 & Loc* (HN, NSW). **Lai Chau:** Phong Tho, Muong So, Vang Khon, cult. in village, coll. from steep limestone ridge behind village, 23 Mar 1999, *Hill 5064 & Loc* (HN, NSW); Phong Tho, Muong So, Phuong Lanh, 24 Mar 1999, *Hill 5065 & Loc* (HN, NSW). **Lao Cai:** Lao Cai city, cult., coll. 10 km to W or SW, 24 Mar 1999, *Hill 5066 & Loc* (HN, NSW); Bao Yen, Thuong Ha, 3rd village, 25 Mar 1999, *Hill 5067 & Loc* (HN, NSW). **Ninh Binh**: Cuc Phuong, 29 Dec 1994, *Hiep 2029* (HN); Nho Quan, Cuc Phuong National Park, near gate, cult. on old village site, thought to have been collected locally, 18 Mar 1999, *Hill 5049 & Loc* (HN, NSW); Nho Quan, Cuc Phuong National Park, near Bong, 18 Mar 1999, *Hill 5051 & Loc* (HN, NSW); Nho Quan, Cuc Phuong National Park, cult. in village at entrance gate, coll. nearby, 19 Mar 1999, *Hill 5052 & Loc* (HN, NSW). **Son La:** Moc Chau, Van Ho, Hang Trung, 20 km E of Moc Chau, 21 Mar 1999, *Hill 5057 & Loc* (HN, NSW). **Thai Nguyen:** Vo Nhai, Lau Thuong, Lung Hang, cult. near house, coll. 500 m to east, 16 Mar 1999, *Hill 5041, 5042 & Loc* (HN, NSW). **Thanh Hoa:** Nhu Xuan, Ben En National Park, 13 Oct 1996, *Hiep 2116, 2117, 2118* (HN); Nhu Thanh, Hai Van, Xuan Lai,19 Mar 1999, *Hill 5054 & Loc* (HN, NSW); Ngoc Lac, Minh Son, Minh Chau, cult. in village, coll. nearby, 20 Mar 1999, *Hill 5055 & Loc* (HN, NSW); Lang Chanh, Dong Luong, Thung, 20 Mar 1999, *Hill 5056 & Loc* (HN, NSW). **Tuyen Quang:** Chiem Hoa, Yen Nguyen, Dong Vang, 29 Mar 1996, *Yang & Hiep 768* (HN); 31 Mar 1996, *Yang & Hiep 774* (HN); Na Hang, Pac Ban, Nam Chang, 30 Mar 1996, *Yang & Hiep 769, 770* (HN); *Hiep 2083* (HN); Yen Son, Tien Bo, Goc Thi, cult in garden, coll from wooded hills close by, 17 Mar 1999, *Hill 5046 & Loc* (HN, NSW). **Hybrid swarm**: ***Cycas dolichophylla* X *C. ferruginea* VIETNAM: Thai Nguyen**: Vo Nhai, Lau Thuong, Lang Hang, cult. near house, coll. 500 m to east, 16 Mar 1999, *Hill 5039, 5040 & Loc* (HN, NSW); Quang Son, Dong Hai, cult. in gardens, coll. from steep limestone cliffs 3–400 m to W, 16 Mar 1999, *Hill 5045 & Loc* (HN, NSW).

7. *Cycas diannanensis* Z.T.Guan & G.D.Tao, *Sichuan Forestry & Desig.*, 1995: 1 (1995).

Type: China, Yunnan, S. Gejiu County, Manhao, alt 700–1120 m., *G.D. Tao 95014* (holo ISBC).

Cycas parvulus S.L.Yang, in D.Y.Wang, *Cycads China*: 93 (1996).

Type: China, Yunnan, around Mengdian village, Honghe County, 5 km from Yuanjiang [River], *S.L. Yang 317* (holo HWA n.v.; iso FTG n.v., PE). Study of the isotype held in PE and of living plants has led to the inclusion of this taxon in the synonymy of *C. diannanensis.*

Cycas pectinata var. *manhaoensis* C.Chen & P.Yun, *Acta Bot. Yunnan.* 17: 400 (1995).

Type: China, Yunnan, Gejiu, Manhao, 1210 m., *M.C. Cai & P. Yun*, 22, 19 Jun. 1995 (holo YUN). Included in the synonymy of *C. diannanensis* by Guan and Tao (1995).

Literature: Wang (1996, and also as *C. parvulus*).

Illustrations: Wang (1996, and also as *C. parvulus*).

Etymology: from the municipality of Diannan in Gejiu County, Yunnan Province.

Stems arborescent or acaulescent, to 3 m tall, 25–35 cm diam. at narrowest point, 12–50 leaves in crown. *Leaves* bright green or deep green, highly glossy, 140–330 cm long, slightly keeled or flat (not keeled) in section (opposing leaflets inserted at 160–180° on rachis), with 160–300 leaflets, with white or orange tomentum shedding as leaf expands; rachis terminated by a spine 1–11 mm long or paired leaflets; petiole 45–100 cm long (20–30% of total leaf), glabrous, spinescent for 90–100% of length; basal leaflets not gradually reducing to spines, 30–240 mm long; spines 1–4 mm long. *Median leaflets* simple, strongly discolorous, 130–320 mm long, 9–16 mm wide, inserted at 50–80° to rachis, decurrent for 3–7 mm, narrowed to 2.5–4 mm at base (to 20–30% of maximum width), 10–20 mm apart on rachis, inserted parallel to rachis; section flat; margins slightly recurved, sometimes undulate; apex acute, not spinescent; midrib raised above, raised below. *Cataphylls* linear, pungent, thinly sericeous or lacking tomentum, 120–200 mm long. *Pollen cones* narrowly ovoid, yellow, 50–65 cm long, 9–13 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 35–60 mm long, 15–25 mm wide, fertile zone 30–50 mm long, sterile apex 4–10 mm long, raised; apical spine rudimentary, sharply upturned, 0–2 mm long. *Megasporophylls* 16–24 cm long, grey-tomentose; ovules 4–8, glabrous; lamina orbicular or ovate, 65–140 mm long, 55–140 mm wide, deeply pectinate, with 30–52 soft lateral spines 10–50 mm long, 1.5–4 mm wide, apical spine distinct from lateral spines, 10–45 mm long, 7–15 mm wide at base. *Seeds* ovoid, 28–40 mm long, 20–32 mm wide; sarcotesta yellow, not pruinose, 3–4 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Distinguishing features: within the group of Chinese cycads with soft microsporangiate cones, loose, freely peeling sarcotesta lacking a fibrous layer and verrucose sculpting of the sclerotesta (Section *Stangerioides*), this species is distinguished at once by the very long, prominent and pungent cataphylls, and also by the small seeds, broad leaflets with slightly recurved, sometimes undulate margins, leaflets that are flat and not twisted on the rachis, and a large megasporophyll apex with a broad apical spine.

Distribution and habitat: a widespread species through central and eastern Yunnan, along the Hong He valley between Hekou and Shuangbai (Fig. 2). This species occurs on a range of substrates from limestone to shale and schist, usually on steep slopes high on ridges, between about 600 and 1800 m. Original vegetation was closed evergreen forest in the cloud zone, although today it is often severely degraded to grassland or scrubby secondary regrowth.

Conservation status: this species is moderately abundant over a considerable area in central and eastern Yunnan province, but many populations are now depleted. Ver 3.1:IUCN (2001) status is **VU** (Donaldson 2003).

Selected specimens examined: CHINA: Yunnan: Gejiu county, Manhao, cult. in the garden of Lushuihe Hydroelectric Station Guest House, *Chen, Hong, Chu, Hill & Stevenson 16, 17 (Hong 369,370),* 8 Jul 2000 (PE, YAF, IBSC, NSW, NY);Gejiu county, Manhao, Gougunpo, wild, *Chen, Hong, Chu, Hill & Stevenson 12 (Hong 351),* 7 Jul 2000 (PE, YAF, NSW, NY); Juanjiang county, cult. in Qingshuihe Huashiban Hydroelectric Station, *Chen, Hong, Hill & Stevenson 23, 24 (Hong 408, 409),* 15 Jul 2000 (PE, YAF, IBSC, NSW, NY);Xinping county, Yiao Jie, cult. in hospital garden, coll. nearby, *Chen, Hong, Hill & Stevenson 25, 26 (Hong 410, 411),* 16 Jul 2000 (PE, YAF, IBSC, NSW, NY); Xinping county, Shui Tang, cult. in school garden, coll. nearby, *Chen, Hong,Hill & Stevenson 27 (Hong 412),* 16 Jul 2000 (PE, YAF, IBSC, NSW, NY); Xinping county, Ga So, wild, *Hong 229,* 12 Dec 1999 (YAF); Shuang Bai county, *Li et al. 2216,* 23 Apr 1999 (YAF).

8. *Cycas collina* K.D.Hill, H.T.Nguyen & L.K.Phan, Bot. Rev. 70(2): 142 (2004).

Type: Vietnam: Son La: Mai Son, between Hat Lot and Bac Yen, 400–900 m alt., 5 Apr 1996, *S.L. Yang 777 & H.T. Nguyen* (holo HN).

Literature: Cheng et al. (1975, as *C. siamensis*), Wang (1996, as *C. balansae*).

Illustrations: Cheng et al. (1975, as *C. siamensis*), Wang (1996, as *C. balansae*).

Etymology: from the Latin *collinus*, pertaining to hills, from the occurrence at moderate to high elevations in mountainous country.

Vernacular: Chinese - *kong-que-bao-dan, shan-ba-buo, shen-xian-mi, xiang-wei-cai* (Walters & Yang 1994, as *C. simplicipinna*; Bonta & Osborne 2007, as *C. simplicipinna*).

Stems acaulescent, 10–20 cm diam. at narrowest point; 2–10 leaves in crown. *Leaves* deep green, highly to semiglossy, 180–330 cm long, slightly keeled (opposing leaflets inserted at 150–180° on rachis), with 90–190 leaflets, with orange and white tomentum shedding as leaf expands; rachis usually terminated by paired leaflets; petiole 70–190 cm long (35–55% of total leaf), glabrous, spinescent for 85–100% of length; basal leaflets not gradually reducing to spines, 120–260 mm long; spines 1–3 mm long. *Median leaflets* simple, strongly discolorous, 250–410 mm long, 15–23 mm wide, inserted at 60–85° to rachis, decurrent for 2–8 mm, narrowed to 2.5–4 mm at base (to 10–25% of maximum width), 16–27 mm apart on rachis, inserted parallel to rachis; section flat or slightly keeled; margins flat, often undulate; apex softly acuminate, not spinescent; midrib raised above, flat or slightly raised below, narrow. *Cataphylls* narrowly triangular, soft, pilose, 50–80 mm long. *Pollen cones* narrowly ovoid or fusiform, yellow, 25–60 cm long, 6–10 cm diam; microsporophyll lamina soft, not dorsiventrally thickened, 25–40 mm long, 14–19 mm wide; fertile zone 22–36 mm long, sterile apex 2–4 mm long, level; apical spine absent. *Megasporophylls* 8–14 cm long, yellow-tomentose, tomentum shedding; ovules 2–4, glabrous; lamina ovate, 50–70 mm long, 30–70 mm wide, deeply pectinate, with 12–22 soft lateral spines 15–35 mm long, 2 mm wide; apical spine not distinct from lateral spines. *Seeds* ovoid, 25–27 mm long, 20–22 mm wide; sarcotesta yellow, not pruinose, 2 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: Chinese authors have misapplied the name *C. siamensis* to this taxon (Cheng et al. 1975). Later authors applied the names *C. simplicipinna* and *C. balansae* (Wang 1996; Chen & Stevenson 1999).

Distinguishing features: the larger and often more numerous leaves with more numerous leaflets and the larger male cones with rounded microsporophylls distinguish this species from *C. simplicipinna* and *C. balansae*. It is one of the complex of closely related acaulescent taxa with soft pollen cones, loose, freely peeling sarcotesta lacking a fibrous layer and verrucose sculpting of the sclerotesta (Section *Stangerioides*) that is distributed through northern Vietnam, Laos, northern Thailand and Yunnan and Guangxi in southern China. The lack of a distinct apical spine on the microsporophyll further distiguish this species within the group.

Distribution and habitat: locally frequent although not in dense stands, in more sheltered sites in deep shade in tall closed evergreen forests, mainly in the Sichuangbanna region of southern Yunnan province, China (Fig. 2). Also in mountainous regions mostly in Son La province in the north of Vietnam, above about 500 metres elevation, in evergreen or partly deciduous forests or woodlands or bamboo thickets on steep slopes of mountain ridges. Substrate varies from red clay soils on limestone to loamy soils on metasediments. Probably also in Laos and Myanmar.

Conservation status: a widespread species, although not occurring in large or dense populations. Although its habitat is continually being reduced, many populations remain. Ver 3.1:IUCN (2001) status is **VU** (Donaldson 2003).

Selected specimens examined: CHINA: Yunnan*:* Pe-tsen, *Cavalerie 7106*, 1913 (K); Mengla county, Menglun Nature Reserve, *Chen, Hong, Hill & Stevenson (Hong 376–380)*, 12 Jul 2000 (YAF, PE); Jinghong county, Xishuangbanna region, Xaio Mung Yang Nature Reserve, *Chen, Hong, Hill & Stevenson (Hong 395, 396–400)*, 12 Jul 2000 (YAF, PE); dense forests of Nam Ha valley, beyond Muang Hai and Keng Hung, *J.F. Rock 2500*, 17 Feb 1922 (K); between Keng Hung and Muang Hing, 4000', *Rock 2654*, 25 Feb–1 Mar 1922 (E). **Cult.:** nursery of Nanning Forestry Research Centre, Nanning Guangxi, collected from Xishuangbanna region Yunnan, *Chen, Zhong & Hill 4*, 7 Nov 1998 (NSW, PE). **VIETNAM: Son La:** Yen Chau, Chieng Don, Chieng Dong pass, ca 8–900 m alt., *Hill 5061 & Loc*, 21 Mar 1999 (HN, NSW); Thuan Chau, Chieng Pac, Phang pass 21 km from Son La, ca 8–900 m alt., *Hill 5062 & Loc*, 22 Mar 1999 (HN, NSW); Phong Lai, ca 8–900 m alt., *Hill 5063 & Loc*, 22 Mar 1999 (HN, NSW); Mai Son, between Hat Lot and Bac Yen, 400–900 m alt., *Yang 777, 778 & Hiep*, 5 Apr 1996 (HN).

Intergrades: C. collina – C. dolichophylla: VIETNAM: Son La: Moc Chau, Chieng Hac, Chieng Pan, ca 500 m alt., *Hill 5060 & Loc*, 21 Mar 1999 (HN, NSW).

9. *Cycas balansae* Warb., Monsunia 1: 179 (1900).

Cycas siamensis subsp. *balansae* (Warb.) Schuster, Pflanzenr. 99: 81 (1932).

Type: (lectotype, here designated) Tonkin (Vietnam), Hanoi, Mar 1889, *B. Balansa 4084* (P; isolecto G-DC, G, K). See comment below.

C. shiwandashanica Hung T.Chang & Y.C.Zhong, Chinese Bull. Bot. 12: 12 (1995).

Type: Guangxi: Nasuo, Fangchenggang City, in broad-leaved forest, *Y.C. Zhong 88015*, 30 Jul 1990 (holo GXF; iso PE, SYS). Included in the synonymy of *C. balansae* by Chen and Stevenson (1999).

C. *palmatifida* Hung T. Chang, Y.Yuan Huang &Y.C.Zhong, Acta Sci. Nat. Univ. Sunyatseni 37(4): 7 (1998).

Type: China, Guangxi, cult. Nanning arboretum, *H.X. Zheng & Y.Y. Huang 98002*, 19 Apr 1998 (holo SYS n.v.). Although specimens were not seen, the living plant that the specimens were taken from was studied (see below), leading to the placement of this taxon in the synonymy of *C. balansae.*

C. tonkinensis, in part, sensu De Laubenfels and Adema (1998).

Literature: Wang (1996, and also as *C. shiwandashanica*), Chen and Stevenson (1999).

Illustrations: Cheng et al. (1975, as *C. siamensis*); Wang (1996, and also as *C. shiwandashanica*).

Etymology: honouring French naturalist and botanical explorer Benedict Balansa (1825–1892), who collected extensively for the Museum of Natural History in Paris, and spent the years 1885 to 1892 collecting in Tonkin (North Vietnam), where he died.

Stems acaulescent, 12–20 cm diam. at narrowest point, 4–9 leaves in crown. *Leaves* deep green, highly glossy to semiglossy, 120–260 cm long, slightly keeled to flat in section (opposing leaflets inserted at 160–180° on rachis), with 90–160 leaflets, with dark brown tomentum shedding as leaf expands or persistent on petiole, rachis consistently terminated by paired leaflets; petiole 40–160 cm long (30–40% of total leaf), pubescent with dark purple-brown tomentum, spinescent for 100% of length, basal leaflets not gradually reducing to spines, 90–210 mm long; spines 4–10 mm long. *Median leaflets* simple, strongly discolorous, 220–300 mm long, 10–15 mm wide, inserted at 75–85° to rachis, decurrent for 5–8 mm, narrowed to 3–4 mm at base (to 25–35% of maximum width), 11–21 mm apart on rachis, inserted parallel to rachis, stiff in texture; section flat; margins flat or slightly recurved, apex softly acuminate; not spinescent, midrib raised above, flat below. *Cataphylls* narrowly triangular, soft, pilose, 60–70 mm long. *Pollen cones* fusiform, yellow, 20–25 cm long, 4–7 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 16–30 mm long, 11–14 mm wide, fertile zone 14–28 mm long, sterile apex 2–4 mm long, level, apical spine absent. *Megasporophylls* 8–12 cm long; brown-tomentose; ovules 2–4, glabrous; lamina ovate, 40–60 mm long, 30–55 mm wide, deeply pectinate, with 14–24 soft spines 25–40 mm long, 2–3 mm wide, apical spine not distinct from lateral spines. *Seeds* ovoid, 25–27 mm long, 20 mm wide, sarcotesta yellow, not pruinose, 2 mm thick; fibrous layer absent; sclerotesta lightly verrucose; spongy endocarp absent.

Typification: described by German botanist Otto Warburg in 1900. A single collection was cited as 'Im Herbarium Barbey finde ich von Balansa sub Nr. 4084 gesammelte ♂ Zapfen aus Tongking, nahe Hanoi aus einem Tempelhof stammend…' Warburg types were mostly held by B, and Schuster (1932) cited a specimen probably from B which would probably have been the type: 'Tongking: Village du papier bei Hanoi, im Hof einer Pagode (B. Balansa IV. 1889, n. 4084).' This specimen was evidently destroyed in WW2. The specimens in G, K and P were not annotated by Warburg or Schuster, and may not have been seen by either. Most of these specimens are of microsporangiate cone material only, although the material held in P comprises two sheets, one microsporangiate cone portion and one leaf portion. The microsporangiate cone sheet is annotated 'B. Balansa - Pl. du Tonkin - 1885–1889/Nr. 4084/Dioique. Frondes de deux metres de hauteur/ Tongking: Village du papier près de Hanoi, dans la/cour d'une pagode/Avril 1889' [Dioecious. Fronds 2 m high. Paper village near Hanoi, in the garden of a pagoda]. The two sheets held in P are here designated the lectotype.

Distinguishing features: this species is one of the complex of closely related mostly acaulescent taxa that is distributed through southern China, northern Vietnam, Laos, and northern Thailand (Section *Stangerioides*). It is distinguished by the few long leaves with long petioles bearing long slender spines and a deep purple-brown tomentum that is often persistent. Microsporangiate cones are intermediate in size with rounded microsporophylls which lack any apiculus. Megasporophylls are reduced, with a few, long and slender divisions on the lamina. Seeds are small.

Distribution and habitat: locally frequent although not in dense stands, in more sheltered sites in deep shade in tall closed evergreen forests, in the Shiwandashan (mountains) in coastal south-eastern Guangxi province of China, and extending into the region north-west and north-east of Hanoi in Vietnam (Fig. 2). On loamy soils over schists or granites.

Conservation status: Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003).

Selected specimens examined: CHINA: Guangxi: Cult. grounds of Nanning Forestry Research Centre, Nanning (Type plant of *Cycas palmatifida*), collected from Fangcheng County, *Chen, Zhong & Hill 01*, 7 Nov 1998 (NSW, PE); cultivated in Ping Mu village, Na Suo town, Fangcheng county, Guangxi province, collected from Fang Chen Shang Yue reserve, *Chen, Zhong & Hill 28*, 19 Nov 1998 (NSW, PE). **VIETNAM: Hai Phong:** jardins a Hai Phong, 1885, *Balansa 563* (P). **Ha Nam:** Ke So, forte ex montibus Kien Khe, 25 May 1889, *Bon 4146* (P). **Lang Son:** Dinh Lap, Dinh Lap townlet (21°32'25"N 107°06'32"E), 12 Mar 1999, *Hill 5026, Loc & Dzu* (HN, NSW); Dinh Lap, Bac Lang, Ban Ha, 27 Mar 1996, *Yang & Hiep 763* (HN); Phu Son, Bac Son, Na Danh, 27 Mar 1996, *Yang & Hiep 765* (HN). **Quang Ninh:** Hoanh Bo, Tan Dan, Hang Tran (21°08'17"N 106°52'50"E), 11 Mar 1999, *Hill 5022, 5023, Loc & Dzu* (HN, NSW); Tien Yen, Dien Xa, Na Tru (21°22'47"N 107°17'32"E), 12 Mar 1999, *Hill 5025, Loc & Dzu* (HN, NSW); Cam Pha, 26 Mar 1996, *Yang & Hiep 758* (HN); Quang Nghia, Quang Ha, 27 Mar 1996, *Yang & Hiep 761* (HN); Hai Lang, Tien Yen, 25 Mar 1996, *Yang & Hiep 767* (HN). **Thai Nguyen:** Dai Tu, Ky Phu, Xom Gio, 19 Jan 2000, *Hiep 4117 & Hill* (HN, NSW). **Tuyen Quang:** Son Duong, Son Nam, cult. in restaurant, coll from NW side of Tam Dao range, Tam Dao, Dai Dinh, Den Thong, 17 Mar 1999, *Hill 5048 & Loc* (HN, NSW).

10. *Cycas tanqingii* D.Y.Yang, Cycads China: 134 (1996).

Type: China, Yunnan, Luchun County, *D.Y. Wang 5538* (holo SZG; iso NF n.v.).

Illustrations: Wang (1996).

Etymology: honouring Tan-Qing, director of the Shenzhen Fairy Lake Botanic Garden at the time this species was described.

Stems arborescent or acaulescent, to 2 m tall, 25–30 cm diam. at narrowest point, 4–7 leaves in crown. *Leaves* deep green, highly glossy, 190–360 cm long, flat (not keeled) in section (opposing leaflets inserted at 170–180° on rachis), with 100–160 leaflets, with orange tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 70–190 cm long (40–50% of total leaf), petiole glabrous, spinescent for 90–100% of length; basal leaflets not gradually reducing to spines; spines 1–4 mm long. *Median leaflets* simple, strongly discolorous, 300–450 mm long, 15–22 mm wide, inserted at 65–85° to rachis, decurrent for 2–3 mm, narrowed to 5–6 mm at base (to 20–30% of maximum width)15–27 mm apart on rachis, (inserted parallel to rachis); section flat; margins slightly recurved; apex aristate, not spinescent; midrib raised above, raised below. *Cataphylls* narrowly triangular, soft, pilose to densely floccose, 50–80 mm long. *Pollen cones* fusiform, yellow to orange, to 40 cm long, 5–8 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 25–30 mm long, 10–13 mm wide, fertile zone 22–28 mm long, sterile apex 2–3 mm long, level to raised; apical spine slender, appressed, sharply upturned, 1.5–2 mm long. *Megasporophylls* 10–12 cm long, brown-tomentose; ovules 2, glabrous; lamina orbicular, 50–55 mm long, 50–65 mm wide, deeply pectinate, with 6–9 soft spines 15–40 mm long, 1–3 mm wide, apical spine not distinct from lateral spines, 20–45 mm long, 7–30 mm wide at base. *Seeds* subglobose to ovoid, 35–40 mm long, 30–35 mm wide; sarcotesta yellow, not pruinose, 2 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Distinguishing features: the robust habit with large leaves and long petioles, large microsporangiate cones and seeds distinguish this species within Section *Stangerioides*. *C. tanqingii* differs from *C. dolichophylla* in the longer and more widely spaced leaflets that are not broad-based and rounded at the base, and the longer petioles, although it may be more closely allied to *C. chevalieri* from Laos and Vietnam, differing in the overall larger stature.

Distribution and habitat: remote and mountainous country in south-eastern Yunnan Province, China (Fig. 2), possibly also across the border in Vietnam, in closed evergreen forest.

Conservation: Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003).

Selected specimens examined: CHINA: Yunnan: Luchun county, Erpu, along Xiaohejiang River (and Heishuhe River), *Chen, Hong, Chu, Hill & Stevenson 13–15 (355–357)*, 9 Jul 2000 (PE, YAF, IBSC, NSW, NY). **VIETNAM: Lai Chau:** reported by forestry workers from Luchun County, China, to occur on Vietnamese side of the Hejiang [river], no voucher.

11. *Cycas szechuanensis* Cheng & L.K.Fu, Acta Phytotax. Sin. 13(4): 81, T. 1, Fig. 7–8 (1975).

Type: China, cultivated in Fuhu temple, Mt Emei, Sichuan, *J.H. Zhiong et al. 33221* (holo PE; iso HWA, IBSC, SZG, IBK) [citation is in Chinese].

Stems arborescent, to 2 m tall, 15–33 cm diam. at narrowest point; 6–40 leaves in crown. *Leaves* deep green, highly glossy, 120–380 cm long, slightly keeled to flat (not keeled) in section (opposing leaflets inserted at 160–180° on rachis), with 90–220 leaflets, with dark brown tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets or a spine 8–25 mm long; petiole 50–130 cm long (25–40% of total leaf), petiole glabrous, spinescent for 95–100% of length; basal leaflets not gradually reducing to spines, 90–260 mm long; spines 1–3 mm long. *Median leaflets* simple, strongly discolorous, 230–440 mm long, 14–21 mm wide, inserted at 70–85° to rachis, decurrent for 4–7 mm, narrowed to 3.5–7 mm at base (to 20–50% of maximum width), 10–24 mm apart on rachis, twisted (insertion not parallel to rachis); section flat; margins flat; apex acute, not spinescent; midrib raised above, flat below to raised below (slightly). *Cataphylls* narrowly triangular, soft, pilose, 50–60 mm long. *Pollen cones* not seen. *Megasporophylls* 16–24 cm long, brown-tomentose; ovules 4–8, glabrous; lamina orbicular, 70–100 mm long, 60–110 mm wide, deeply pectinate, with 28–42 soft lateral spines 30–50 mm long, 2–4 mm wide, apical spine not distinct from lateral spines or distinct from lateral spines, 12–40 mm long, 2–8 mm wide at base. *Seeds* ovoid, to 45 mm long, to 35 mm wide; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Distinguishing features: *C. szechuanensis* is allied to *C. taiwaniana*, differing in the orbicular megasporophyll lamina that lacks a broad apical spine (2–8 mm wide in subsp. *fairylakea*, 7–30 mm wide in *C. taiwaniana*) and the larger seeds.

Two subspecies are recognised.

Key to the subspecies

Cataphylls less than 70 mm long, pilose .... subsp. *szechuanensis*
Cataphylls more than 70 mm long, thinly sericeous .... subsp. *fairylakea*

11A. *Cycas szechuanensis* subsp. *szechuanensis*

Etymology: from Szechuan (Sichuan) province, with the Latin termination -ensis, place of origin, in the mistaken assumption that this species was native to the region from which the cultivated type specimen was collected.

Stems arborescent, to 2 m tall, 15–25 cm diam. at narrowest point; 6–20 leaves in crown. *Leaves* deep green, highly glossy, 120–380 cm long, slightly keeled to flat (not keeled) in section (opposing leaflets inserted at 160–180° on rachis), with 90–220 leaflets, with dark brown tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 50–130 cm long (30–40% of total leaf), petiole glabrous, spinescent for 95–100% of length; basal leaflets not gradually reducing to spines, 90–260 mm long, spines 1–3 mm long. *Median leaflets* simple, strongly discolorous, 230–440 mm long, 14–21 mm wide, inserted at 80° to rachis, decurrent for 5–7 mm, narrowed to 3.5–4 mm at base (to 20–25% of maximum width), 10–24 mm apart on rachis, twisted (insertion not parallel to rachis); section flat; margins flat; apex acute, not spinescent; midrib raised above, flat below to raised below (slightly). *Cataphylls* narrowly triangular, soft, pilose, 50–60 mm long. *Pollen cones* not seen . *Megasporophylls* 16–24 cm long, brown-tomentose; ovules 4–8, glabrous; lamina orbicular, 70–100 mm long, 70–110 mm wide, deeply pectinate, with 28–34 soft lateral spines 30–50 mm long, 2–4 mm wide, apical spine not distinct from lateral spines. *Seeds* ovoid, to 45 mm long, 35 mm wide; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: described in 1975 by Chinese botanists Cheng and Fu. This subspecies was rediscovered in the wild only in 1999, in eastern Fujian Province. Before this, it had been presumed extinct, or at one time regarded as conspecific with *C. guizhouensis* (Chen & Stevenson 1999).

Distribution and habitat: known only from eastern Fujian Province (Fig. 3). This subspecies grows in moist closed forests or woodlands.

Conservation status: this species is listed by the 1997 IUCN Red List of Threatened Plants (Walter & Gillett 1998; as *C. guizhouensis*) as category Ex. It has since been rediscovered in the wild, although known populations are severely degraded, and the overall reduction in recent years indicates that this species should probably be regarded as critically endangered. Ver 3.1:IUCN (2001) status is **CR** (Donaldson 2003).

Selected specimens examined: CHINA: Fujian: Yuing Tai County, Chin Yung town, Gu An village, cult., collected in district, *Chen 99008*, 26 Oct 199 (PE); Sha Ming County, Chon Da town, 500 m E of town, wild in hills, *Chen 99001*, 23 Oct 1999 (PE). **Cult.:** cultivated Guilin Institute of Botany, plants obtained from Guangdong many years ago, *Chen, Zhong & Hill 44*, 28 Nov 1998 (NSW, HN, K, NY, PE).

11B. *Cycas szechuanensis* subsp. *fairylakea*, (D.Yue Wang) N.Liu, Proc. Sixth Int. Conf. Cycad Biol.: 2 (2004).

Cycas fairylakea D.Yue Wang, Cycads China: 54 (1996).

Type: China, Guangdong, cultivated in South China Botanical Garden, *D.Y. Wang & H. Peng 2978*, 16 May 1994 (holo SZG; iso IBSC n.v., NF n.v.).

Literature: Wang (1996).

Etymology: from the Shenzhen Fairy Lake Botanic Garden, from which the cultivated type specimen was collected.

Stems arborescent, to 0.5–1.8 m tall, 22–33 cm diam. at narrowest point. 20–40 leaves in crown. *Leaves* deep green, highly glossy, 210–270 cm long, slightly keeled or flat (not keeled) in section (opposing leaflets inserted at 170–180 degrees on rachis), with 126–162 leaflets; rachis frequently terminated by a spine 8–25 mm long; petiole 49–80 cm long (20–35 % of total leaf), glabrous, spinescent for 90–100 % of length; basal leaflets not gradually reducing to spines, spines 1–3 mm long. *Median leaflets* simple, 305–360 mm long, 12–19 mm wide, inserted at 70–85 degrees to rachis, decurrent for 4–6 mm, narrowed to 5–7 mm at base (to 30–50 % of maximum width), 20–22 mm apart on rachis, twisted (insertion not parallel to rachis); section flat; margins flat; apex acute, not spinescent; midrib raised above, flat below. *Cataphylls* linear, soft, thinly sericeous or lacking tomentum, 80–100 mm long. *Pollen cones* not seen. *Megasporophylls* 18–20 cm long, brown-tomentose; ovules 4–6, glabrous; lamina orbicular, 80–90 mm long, 60–70 mm wide, deeply pectinate, with 32–42 soft lateral spines 38–42 mm long, 2–3 mm wide; apical spine usually distinct from lateral spines, 12–40 mm long, 2–8 mm wide at base. *Seeds* not seen.

Historical notes: described at specific rank in 1996 by Chinese botanist D.Y. Yang. This subspecies was rediscovered in the wild only in 2000, near Shenzhen in eastern Guangdong Province. Before this, it had been regarded as conspecific with *C. taiwaniana* (Chen & Stevenson 1999).

Distinguishing features: subspecies *fairylakea* differs from the type subspecies in the presence of a distinctly extended though narrow apical spine on the megasporophyll and the longer, less pilose cataphylls.

Distribution and habitat: known only from eastern Guangdong Province. This subspecies grows in moist closed forests (Fig. 3).

Conservation status: although this subspecies has been rediscovered in the wild, known populations are severely degraded, and the overall reduction in recent years indicates that this subspecies should be regarded as threatened. Ver 3.1:IUCN (2001) status is **CR** (Donaldson 2003).

Selected specimens examined: CHINA: Guangdong: cult. Fairy Lake Botanical Garden, coll. from Fairy Lake 20 years ago, *Chen 2001–51*, 13 Jun 2001 (PE, NSW); Shenzhen, Tanglangshan, Changyuancun village, *Chen, Hill, Li, Wang, Zhang & Liu TL 001, 002, 003, 004, 005, 006*, 12 Jun 2001 (PE, NSW, SZG); *Liu, Jian, Ma & Wu 200152904*, 29 May 2001 (PE, NSW, SZG n.v.).

12. *Cycas taiwaniana* Carruth., J. Bot. 31: 1–3, Plate 331 (1893).

Type: Taiwan, Aug 1867, *Swinhoe s.n.* (holo BM; iso K).

Literature: Wang (1996).

Illustrations: Carruthers (1893).

Etymology: from Taiwan, from where this species was (erroneously) thought to have originated.

Vernacular: Chinese - *Feng Wei Cao* (phoenix tail grass) or *Feng Wei Jiao* (phoenix tail palm).*hai-tie-ou, Guangdong su-tie, Taiwan su-tie* (Walters & Yang 1994, Bonta & Osborne 2007).

Stems arborescent or acaulescent, to 3.5 m tall, 15–30 cm diam. at narrowest point; 12–30 leaves in crown. *Leaves* deep green, highly glossy, 150–300 cm long, slightly keeled or flat (not keeled) in section (opposing leaflets inserted at 160–180° on rachis), with 140–300 leaflets, with orange or brown tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 40–150 cm long (30–60% of total leaf), petiole glabrous, spinescent for 100% of length; basal leaflets not gradually reducing to spines c. 25 mm long; spines 1–4 mm long. *Median leaflets* simple, strongly discolorous, 180–440 mm long, 9–16 mm wide, inserted at 45–85° to rachis, decurrent for 5–6 mm, narrowed to 3–5 mm at base (to 25–30% of maximum width), 10–24 mm apart on rachis, twisted (insertion not parallel to rachis); section flat; margins slightly recurved; apex aristate, spinescent; midrib raised above, flat below. *Cataphylls* narrowly triangular, pungent, pilose to densely floccose, 85–130 mm long. *Pollen cones* narrowly ovoid to fusiform, yellow, 30–45 cm long, 8–10 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 20–30 mm long, 5–15 mm wide, apex level, apical spine absent. *Megasporophylls* 15–22 cm long, brown-tomentose; ovules 2–6, glabrous; lamina orbicular, 70–120 mm long, 55–70 mm wide, deeply pectinate, with 24–52 soft lateral spines 20–42 mm long, 1–2 mm wide, apical spine distinct or not distinct from lateral spines, 20–45 mm long, 7–30 mm wide at base. *Seeds* subglobose to ovoid, 28–36 mm long, 20–30 mm wide; sarcotesta yellow, not pruinose, 2 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: *C. taiwaniana* was described in 1893 by English botanist and palaeontologist William Carruthers (1830–1922). The species was based on specimens he discovered in the herbarium of Henry F. Hance (a British consular officer in China from 1844 to 1886), which had since been acquired by the British Museum. These were collected by Robert Swinhoe, another British consular officer, who had also sent specimens to J.D. Hooker at Kew. The first of the latter was a single megasporophyll sent from the British Consulate at Amoy [Xiamen], where Swinhoe was the British

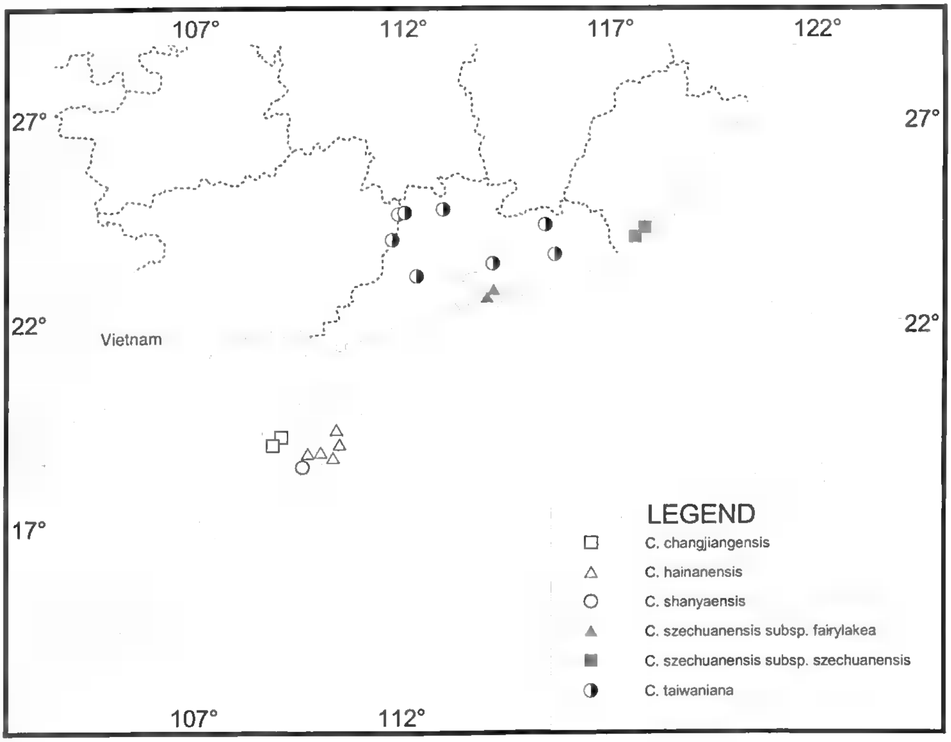

Fig. 3. Distribution of *C. changjiangensis, C. hainanensis, C. shanyaensis, C. szechuanensis* and *C. taiwaniana.*

representative, on 21 Aug 1867. This specimen was accompanied by a letter to Hooker in which Swinhoe wrote 'Among the [silkworm] cocoons now sent you will find two specimens of an extraordinary leaf. I have worked at it in vain to make out its relations. It looks like a botanical caricature of a Pelican. The Chinese call it Hai-te-koe or sea-iron fowl (sea-iron is the name given to the coral submarine trees), and use it to flavour tea. They tell me it is found in fresh-water wells, but it is so rare here that I have not been able to ascertain how it grows, and whether the leaf constitutes the entire plant…'. Swinhoe later the same year acquired more complete material, and sent additional specimens to both Hance and Hooker.

Carruthers in the protologue stated 'No more definite information is contained on the label than that the specimens were collected on the island of Formosa by Mr. Swinhoe, and sent to Dr. Hance in the autumn of 1867, from whose herbarium, as I have said, came the specimen in the British Museum on which the species is founded.' This statement is based on the annotation on the sheet, stating '*Cycas*, L./ *circinalis* L./ Ex insula Formosa,/ autumn 1867 misit/ cl. Swinhoe.' This annotation is not in Swinhoe's hand, and may have been made by Hance. There is no indication from Swinhoe of exactly where the specimens were collected.

Thiselton-Dyer (1902) addressed the problem of the origin of these specimens, and cited correspondence from British representatives in China to Kew. He stated that 'Mr. G. Phillips, H.B.M. consul at Takow [?] and later Swatow [Shantou] took much trouble to find Swinhoe's plant. He eventually discovered it in 1883 "on the hills 60 miles from Swatow" and sent specimens to Kew.' Phillips also wrote to Kew stating that he had never seen the plant in Taiwan, and that it was much sought after as a garden plant on the mainland. Thiselton-Dyer also cited specimens collected in the Lofu-Shan by Ford as this species, but did not recognize a distinction between the mainland and Taiwanese plants.

More recent Chinese accounts (Cheng et al. 1975, Cheng & Fu 1978) correctly apply the name *C. taiwaniana* to the mainland plants, but do not recognise the distinctive nature of the Taiwan plants (see *C. taitungensis*).

Distinguishing features: *Cycas taiwaniana* is placed with the wider group of Chinese species (Section *Stangerioides*) by the soft microsporangiate cones, the loose, freely peeling sarcotesta lacking a fibrous layer and the verrucose sclerotesta. Within this group, it is distinguished by the more robust stature with distinct development of an aerial trunk and a large crown of leaves, and small seeds. Megasporophylls usually have a distinct apex and are larger but extremely variable in outline, as with many of the species in this section. Leaflets are moderately narrow but again highly variable, and distinctly twisted on the rachis.

Distribution and habitat: widespread but sporadic, in Fujian, Guangdong, Guangxi, Guizhou and Hunan Provinces, China (Fig. 3). This species has long been cultivated in Guangdong and Fukien Provinces. Most collections, if not all, are from cultivated plants, and *C. taiwaniana* is now extremely rare in the wild. Reports of *C. taiwaniana* from Taiwan are the result of the misapplication of this name to the Taiwan cycad (*C. taitungensis*).

Conservation status: although originally widespread, this species has been severely depleted by collection from the wild and by habitat destruction over the centuries. Surviving populations are fragmentary and in remote sites and although probably reasonably secure by virtue of inaccessibility, must still be regarded as under threat.

This species is listed by the 1997 IUCN Red List of Threatened Plants as category V, but distribution is recorded in this listing as Hainan Island and Taiwan, which is clearly incorrect. Ver 3.1:IUCN (2001) status is **EN** (Donaldson 2003).

Selected specimens examined: CHINA: Guangxi: cultivated, He Xian Institute of Forestry, collected from near Guangdong border to east, from "soil mountain" in grass, *Chen, Zhong & Hill 38,* 25 Nov 1998 (NSW, NY, PE); cultivated Da Ning town, in schoolyard, collected from wild near Sang Ho village ca 10 km (3 hours walk) to east, growing naturally in semishade along stream, *Chen, Zhong & Hill 42,* 26 Nov 1998 (NSW, PE); cultivated, Ling Chuan city, N of Guilin, Guangxi, Plants collected from wild near Gui Bei, 150 km N of Guilin, growing along stream in semishade, red soil mountain, not limestone (probably sandstone), plants also across border in Hunan province, *Chen, Zhong & Hill 45,* 29 Nov 1998 (NSW, PE). **Guangdong:** Chin Tong village, San Sue town, in Li An Shan (mountains), probably cultivated, but said to occur naturally nearby, *Chen, Zhong & Hill 41,* 26 Nov 1998 (NSW, FTG, HN, K, KL, L, MO, NY, P, PE); Gaoyao County, *Shi 12204* (IBSC); Pingyuan County, *Deng 68300* (IBSC), *Deng 4410* (IBSC); Ruyuan County, *Tan 32* (IBSC), *Tan & Huang 321* (IBSC); Wengyuan County, *Lau 2653* (IBSC), *Lau 24847* (IBSC); Dinghu Shan, Zhaoqing County, *Xie & Li 00156* (IBSC). **Cult.:** Fujian, Xiamen, *Lin 2916* (IBSC); Guangdong, *Chen 88377* (PE); cultivated, Fen An Shi temple, Pu Meng town, *Chen, Zhong & Hill 39,* 25 Nov 1998 (NSW, PE); cultivated, near small market in He Xian city, *Chen, Zhong & Hill 40,* 26 Nov 1998 (NSW, FTG, HN, K, L, MO, NY, PE)

13. *Cycas hainanensis* C.J.Chen, Acta Phytotax. Sin. 13(4): 82, T. 2, Fig. 5–6 (1975).

Type: Hainan: Luilianling, Wangning County, 16 Oct 1961, *Y. Zhong 4706* (holo PE; iso IBSC n.v.).

Cycas lingshuiensis G.A.Fu, Bull. Bot. Res. 24(4): 387–388 (2004), as '*lingshuigensis*'.

Type: Hainan: Lingshui, hill mixed forest, alt 500–600m, 26 Dec 2002, G.A. Fu 10809 (holo HFB n.v.). Placed in the synonymy of *C. hainanensis* following discussions with Chinese botanists (pers. comm.).

Literature: Wang (1996, as *C. taiwaniana* in part and also as *C. fairylakea* in part).

Illustrations: Cheng et al. (1975), Wang (1996, as *C. taiwaniana* in part), Fu (2004, as *C. lingshuigensis*).

Etymology: from its natural occurrence in the island province of Hainan, with the Latin termination *-ensis,* place of origin.

(*C. lingshuiensis* from Lingshui town in southern Hainan province, with the Latin termination -ensis, place of origin. Originally published as *Cycas lingshuigensis* where the specific epithet has been formed incorrectly by the introduction of a superfluous letter 'g')

Vernacular: Chinese - *ci-bing su-tie* (spiny petioled cycad), *feng-huang-dan* (phoenix egg), *Hainan su-tie* (Chen et al. 1995, Walters & Yang 1994, Bonta & Osborne 2007).

Stems arborescent, to 0.3–1.5(–3.5) m tall, 30 cm diam. at narrowest point; 50–80 leaves in crown. *Leaves* bright green, highly glossy, 70–230 cm long, moderately keeled (opposing leaflets inserted at 120–160° on rachis), with 100–280 leaflets, with orange tomentum shedding as leaf expands; rachis usually terminated by paired leaflets; petiole 20–70 cm long (20–30% of total leaf), petiole glabrous, spinescent for 100% of length; basal leaflets not gradually reducing to spines, 140 mm long; spines 1–4 mm long. *Median leaflets* simple, strongly discolorous, 150–300 mm long, 6–10 mm wide, inserted at 40–70° to rachis, decurrent for 2–7 mm, narrowed to 2.5–3 mm at base (to 30–45% of maximum width), 8–15 mm apart on rachis; section slightly keeled; margins slightly recurved; apex acute, spinescent, twisted (insertion not parallel to rachis); midrib raised above, raised below (less prominently). *Cataphylls* narrowly triangular, soft, pilose, 50–90 mm long. *Pollen cones* fusiform, green or cream, c. 40 cm long, 8 cm wide; microsporophyll lamina soft, not dorsiventrally thickened, 38–44 mm long, 19–25 mm wide, fertile zone 30–35 mm long, sterile apex 4–6 mm long, apical spine absent. *Megasporophylls* 16–17 cm long, brown-tomentose; ovules 2–4, glabrous; lamina orbicular, 70–110 mm long, 40–60 mm wide, deeply pectinate, with 15–32 soft lateral spines 25–32 mm long, 2 mm wide, apical spine distinct from lateral spines, 20–30 mm long, 10–25 mm wide at base. *Seeds* subglobose to ovoid, 35–40 mm long, 30–35 mm wide; sarcotesta yellow, not pruinose, 2 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: described in 1975 by Chinese botanist C.J. Chen, from material collected by Y. Zhong Wangning County in 1961. This species was initially contrasted with *C. rumphii*, although we now know that its affinities are quite removed from the latter. Chinese flora accounts recorded this species from only Hainan, although later accounts (Zhou et al. 1990) noted that it was cultivated in Fujian, Guangdong and Sichuan. More recently, a proposal was made that at least the Guangdong plants were taxonomically distinct (Deng, cited by Walters et al. 1995). We now know that the Mainland plants are distinct, and that the type of *C. taiwaniana* belongs here (see discussion under that species).

Distinguishing features: *C. hainanensis* is very close to *C. taiwaniana*, differing in the more keeled leaves with narrower and more crowded leaflets, and the smaller megasporophyll lamina with fewer but longer lateral spines and an often greatly expanded apical spine. Seeds are also distinctly larger.

Distribution and habitat: known only from the wetter eastern parts of Hainan Island (Fig. 3). Wild populations are now very restricted, and this species survives mainly in cultivation. Plants occur from sea level to about 1200 m. elevation, on soils on limestone and volcanic substrates. Climate here is subtropical, and rainfall high (c. 2000 mm annually), and the usual habitat is rainforest.

Conservation status: Ver 3.1:IUCN (2001) status is **EN** (Donaldson 2003).

Selected specimens examined: CHINA: Hainan: Luilianling, Wangning County, *Tang 92586* (PE); southern Wanning County, *Yang NSW 271211*, 30 Oct 1992 (NSW); Qiongdong County, *Liang 68119* (IBSC n.v.); Baoting County, *Liang 68300* (IBSC n.v.); Mt Diaolou, Lingshui County, *Hainan Expedition*, 1959 (PE); Bawangling, Changjiang County, *Chen 92606* (PE). **Cult.:** cultivated at Pingxian Istitute of Forestry, Guangxi, *C.J. Chen, Y.C. Zhong & K.D. Hill 36, 37*, 22 Nov 1998 (NSW, FTG, NY, PE); Haiku Peoples Park, Haiku, Hainan, *Chun 17629* (IBSC n.v., PE).

14. *Cycas shanyaensis* G.A. Fu, Bull. Bot. Res. 26(1): 2-3, Fig. 1 (2006) as '*shanyagensis*'.

Type: China, Hainan, Sanya city, 15 Sep 2003, *G.A. Fu 11022* (holo HFB n.v.).

Etymology: from Shanya city/district in southern Hainan province, with the Latin termination -ensis, place of origin. Originally published as *Cycas shanyagensis* where the specific epithet has been formed incorrectly by the introduction of a superfluous letter 'g'. Also the use of 'shan' (meaning mountain) is not correct when the chinese character used (三) means three and therefore should be 'san'. However, the apparently mistaken usage has been used consistently throughout the paper and is maintained here.

Stems arborescent, to 2.1–3.1 m tall, 20–25 cm diam. at narrowest point. *Leaves* 140–160 cm long, with 130–144 leaflets. Petiole 33 cm long (21–23% of total leaf), glabrous, spinescent for 76–82% of length, spines 2–3 mm long. *Median leaflets* simple, 115–240 mm long, 7–9 mm wide, slightly decurrent margins flat or slightly revolute. *Pollen cones* dark velvety brown conical-cylindric, c. 22 cm long, 3–8 cm wide; microsporophyll lamina, 15–22 mm long, 10–15 mm wide, apical spine mucronate. *Megasporophylls* 11.5–15 cm long, yellow-brown tomentose; ovules 4, glabrous; lamina obovate or flabelliform, 75 mm long, 75–90 mm wide, deeply pectinate, with 15–17 soft lateral spines 15–25 mm long, apical spine, 25–35 mm long to 4 mm wide, with 4–6 lateral spines 5–7 mm long.

Description based entirely on Fu (2006); no specimens have been sighted by Hill.

Historical notes: described in 2006 by Chinese botanist G.A. Fu.

Distinguishing features: *C. shanyaensis* is allied to *C. hainanensis*, differing in the presence of a toothed terminal spine on the megasporophyll and narrower apical spine on megasporophyll lamina.This taxon is accepted here on the basis of the protologue but requires further field study.

Distribution and habitat: known only from southern Hainan Island (Fig. 3). This species grows in mountain mixed forest 700 – 800 m alt.

Conservation status: recommended Ver 3.1:IUCN(2001) status would be **NE.**

Selected specimens (cited by G.A. Fu): CHINA: Hainan: Shan-Ya city, Baolong shan mountain mixed forest, 700-800 m alt., *G.A. Fu 11166, 11173*, 7 May 2004 (HFB n.v.)

15. *Cycas changjiangensis* N.Liu, Acta Phytotax. Sin. 36: 552 (1998).

Cycas hainanensis subsp. *changjiangensis* (N.Liu) N.Liu, Proc. Sixth Int. Conf. Cycad Biol.: 3 (2004).

Type: China, Hainan, Changjiang, 10 Jun 1997, *N. Liu 97002* (holo IBSC n.v.).

Etymology: from Changjiang county in western Hainan province, with the Latin termination -ensis, place of origin.

Stems acaulescent, to 20 cm diam. at narrowest point; 30–60 leaves in crown. *Leaves* bright green, highly glossy, 70–230 cm long, moderately keeled (opposing leaflets inserted at 120–160° on rachis), with 80–220 leaflets, with orange tomentum shedding as leaf expands; rachis usually terminated by paired leaflets; petiole 20–70 cm long (20–30% of total leaf), petiole glabrous, spinescent for 70–100% of length; basal leaflets not gradually reducing to spines, 70–140 mm long; spines 1–4 mm long. *Median leaflets* simple, strongly discolorous, 150–300 mm long, 6–10 mm wide, inserted at 40–70° to rachis, decurrent for 2–7 mm, narrowed to 2.5–3 mm at base (to 30–45% of maximum width), 8–15 mm apart on rachis, twisted (insertion not parallel to rachis); median leaflets section slightly keeled; margins slightly recurved; apex acute, spinescent; midrib raised above, raised below (less prominently). *Cataphylls* narrowly triangular, soft, pilose, 50–90 mm long. *Pollen cones* broadly fusiform, yellow–brown, 15–23 cm long, 4–6 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 15–20 mm long, 5–9 mm wide, , apical spine rudimentary (measurements taken from

Liu 1998). *Megasporophylls* 16–17 cm long, brown-tomentose; ovules 2–4, glabrous; lamina orbicular, 70–110 mm long, 40–60 mm wide, deeply pectinate, with 15–32 soft lateral spines 25–32 mm long, 2 mm wide, apical spine distinct from lateral spines, 20–30 mm long, 10–25 mm wide at base. *Seeds* subglobose to ovoid, 35–40 mm long, 30–35 mm wide; sarcotesta yellow, not pruinose, 2 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: described in 1998 by Chinese botanist N. Liu.

Distinguishing features: *C. changjiangensis* is allied to *C. hainanensis*, differing in the dwarf, largely subterranean habit and the smaller megasporophyll lamina and smaller seeds.

Distribution and habitat: known only from western Hainan Island (Fig. 3). This species grows in seasonally dry woodlands on deeper sandy soils on flatter country.

Conservation status: some quite large populations still exist in the wild, the natural habitat not being good agricultural land. Other populations are severely degraded, and the overall reduction in recent years indicates that this species should be regarded as threatened. IUCN status Ver 3.1:IUCN (2001) status is **EN** (Donaldson 2003).

Selected specimens examined: CHINA: Hainan: Bawangling, Changjiang County, *Chen 92606* (PE). **Cult.:** Nong Nooch Tropical Garden, Thailand (no voucher); Botanic Gardens, Sydney, Australia , seed from Liu 1996, *s.n*, coll. from Changjiang County, Hainan Isl. (NSW).

16. *Cycas bifida* (Dyer) K.D.Hill, Bot. Rev. 70(2): 161 (2004).

C. rumphii var. *bifida* Dyer, J. Linn. Soc., Bot. 26: 560 (1902).

Type: China, Guangxi, Lighthouse pagoda rockhills, Lungchow [Longzhou], *Morse 273*, Dec 1896 (holo K, 2 sheets).

Literature: Cheng et al. (1975, as *C. micholitzii*), Chen and Stevenson (1999, as *C. micholitzii*).

Illustrations: Wang (1996, as *C. micholitzii*).

Etymology: from the Latin *bi-* two and *-fidus* divided, referring to the dichotomously divided leaflets.

Vernacular: Chinese - *long-kou su-tie, cha-ye su-tie* (fork leafed cycad) (Walters & Yang 1994, Chen et al. 1995, Bonta & Osborne 2007).

Stems acaulescent, 10–30 cm diam. at narrowest point, 2–5 leaves in crown. *Leaves* bright green, semiglossy, 200–500 cm long, slightly keeled to flat in section (opposing leaflets inserted at 120–180° on rachis), with 40–80 leaflets, with white and orange tomentum shedding as leaf expands; rachis usually terminated by paired leaflets; petiole 110–160 cm long (35–50% of total leaf), glabrous, spinescent for 90–100% of length; basal leaflets not gradually reducing to spines; spines 1–6 mm long. *Median leaflets* dichotomously branched up to three times, strongly discolorous, 300–600 mm long, 18–25 mm wide, inserted at 45–70° to rachis, decurrent for 10–15 mm, narrowed to 3–4 mm at base (to 14–20% of maximum width), 60–95 mm apart on rachis; section flat; margins flat; apex softly acuminate, not spinescent; midrib raised above, flat below. *Cataphylls* narrowly triangular, soft, pilose, 55–90 mm long. *Pollen cones* fusiform, yellow or cream, 35–55 cm long, 6–8 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 17–28 mm long, 13–16 mm wide, fertile zone 14–25 mm long, sterile apex 2–3 mm long, level, apical spine absent. *Megasporophylls* 7–11 cm long, brown-tomentose; ovules 2–6, glabrous; lamina ovate, 35–100 mm long, 25–50 mm wide, deeply pectinate, with 12–15 soft lateral spines 18–50 mm long, 2–3 mm wide, apical spine distinct or not distinct from lateral spines, 15–70 mm long, 3–8 mm wide at base. *Seeds* flattened-ovoid, 25 mm long, 20 mm wide; sarcotesta yellow, not pruinose, 2 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: this species was first recognized as a distinct taxon in western literature by English botanist Sir William Thiselton-Dyer in 1902, who described it as *C. rumphii* var. *bifida*, on the basis of a leaf fragment collected by H.B. Morse in the Longzhou district of southern Guangxi in 1896. Thiselton-Dyer later received material apparently collected by W. Micholitz in Annam (central Vietnam) from Sander & Sons in 1905, and from Henry Ridley of the Singapore Botanic Gardens at about the same time. He described this as a new species *C. micholitzii* in 1905, noting the similarities with the specimen he had earlier described as *C. rumphii* var. *bifida* but not combining the two. Subsequent authors have regarded them as the same species until recent studies have shown them to be distinct.

Distinguishing features: the most immediately striking feature of this species is the dichotomously divided leaflets. However, this also occurs in several related taxa, and in a horticultural form of *C. revoluta* that is popular in Japan. The subterranean habit, the small, soft microsporangiate cones, the loose, freely peeling sarcotesta lacking a fibrous layer and the verrucose sclerotesta are also all features shared by a wider group of related species (Section *Stangerioides*). Within this group of related species, *C. bifida* is distinguished by the long leaves with glossy, thin-textured, comparatively long and broad leaflets that are dichotomously divided very near to the base. It is most similar to *C. micholitzii* from central Vietnam, and can be distinguished by the larger stature, longer, broader, more lax and glossier leaflets and the larger microsporangiate cones with mostly non-spinescent microsporophylls.

Distribution and habitat: Southern Guangxi Province in China and north-eastern Vietnam (Fig. 4). Locally abundant but many populations are now depleted, in low, scrubby but fairly dense mixed evergreen and deciduous or bamboo woodland, often on red *terra rosa* soils on and around steep karst limestone outcrops, but also on loamy soils over shales and metasandstones. This species is apparently sympatric with *C. multipinnata* in several populations in China, and a range of morphologically intermediate forms that can be interpreted as a hybrid swarm has been observed (see *C. longipetiolula* and *C. multifrondis*, excluded names, below).

Conservation: this species has been severely reduced in numbers both by collecting and by unrestrained agricultural and forestry development. The rarity combined with the unusual habit make it a very highly sought plant by collectors. It is still, however, frequent in many places, especially in Vietnam, and not considered to be at risk in the short term. Treated in the 1997 IUCN Red List as *C. micholitzii* status E for China. Ver 3.1:IUCN (2001) status is **VU** (Donaldson 2003).

Selected specimens examined: CHINA: Guangxi: cult., nursery of Nanning Forestry Research Centre, Nanning, coll. Longzhou County, 7 Nov 1998, *Chen, Zhong & Hill 3* (NSW, PE); cult. Longzhou city park, coll. Longzhou County, 21 Nov 1998, *Chen, Zhong & Hill 35* (NSW, PE). **Yunnan:** Hekou county, *Hong 347, Chen, Hill & Stevenson,* 6 Jul 2000 (YUN, PE). **VIETNAM: Lang Son:** Trang Dinh, Chi Lang, Keo Quang, 13 Mar 1999, *Hill 5027, Loc & Dzu* (HN, NSW);

Binh Gia, Thien Hoa, Thien Thua, 28 Mar 1996, *Yang & Hiep SLY764* (HN). **Cao Bang:** Thach An, Duc Xuan, Tuc Nga, 13 Mar 1999, *Hill 5028, 5030 & Loc* (HN, NSW); Thach An, Tong Con, 3 Dec 1996, *Loc et al. CBL853* (HN). **Tuyen Quang:** Son Duong, Hop Thanh, Dong Dai, *Hiep 4116 & Hill*, 15 Jan 2000 (HN, NSW); Yen Son, Tien Bo, Goc Thi Cult in garden, coll from wooded hills in general vicinity, 17 Mar 1999, *Hill 5047 & Loc* (HN, NSW).

Hybrids: ***Cycas bifida* X *C. multipinnata*: CHINA: Yunnan:** Gejiu county, Yuanjiang River valley, *D.Y. Wang & H. Peng 5523*, 23 Apr 1994 (SZG; holotype of *C. longipetiolula*). Hekou county, Lianhuatang to Makayih, on the border of Hekou and Gejue(Manhao) *Chen, Hong, Hill & Stevenson 011 (Hong 350)*, 6 Jul 2000 (PE, YAF, IBSC, NSW, NY). ***Cycas bifida* X *C. dolichophylla*: VIETNAM: Thai Nguyen:** 15 km NW of Thai Nguyen city - sight record, no voucher, *Nguyen & Hill*, 17 Jan 2000.

17. *Cycas multipinnata* C.J.Chen & S.Y.Yang, Acta Phytotax. Sin. 32(3): 239 (1994). *Epicycas multipinnata* (C.J.Chen & S.Y.Yang) de Laub., in De Laub. & Adema, Blumea 43: 391 (1998).

Type: China, Yunnan, S. Jianshui County, near Red River, 1100 m, Apr 1987, *S.Y. Yang 9202* (holo PE).

Literature: Wang (1996), Chen and Stevenson (1999).

Illustrations: Wang (1996).

Etymology: from the Latin *pinnatus*, pinnate, with the compound prefix *multi-*, many, referring to the complexly branched leaflets.

Vernacular: Chinese - *duoqi su-tie* (multipinnate cycad), *dujuetie* (single leaf cycad) (Chen et al. 1995, Bonta & Osborne 2007).

Stems acaulescent, 14–25 cm diam. at narrowest point, 1–2 leaves in crown. *Leaves* deep green, highly glossy, 200–600 cm long, slightly keeled (opposing leaflets inserted at 120–150° on rachis), bipinnate, with 14–36 leaflets, with white tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 100–350 cm long (50–65% of total leaf), glabrous, spinescent for 90–100% of length; basal leaflets not gradually reducing to spines, 500–720 mm long; spines 1–6 mm long. *Median leaflets* pinnately divided, strongly discolorous, 400–600 mm long, 12–22 mm wide, inserted at 45–70° to rachis, not decurrent, narrowed to 1–3 mm at base (to 8–14% of maximum width), 160–200 mm apart on rachis, pinnules dichotomously branched, segments 15–22 mm wide; section flat; margins flat; apex softly acuminate, not spinescent; midrib raised above, flat below. *Cataphylls* narrowly triangular, soft, pilose, 40–60 mm long. *Pollen cones* fusiform, cream, 25–40 cm long, 6–8 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, apex level or raised, apical spine absent. *Megasporophylls* 11–13 cm long, brown-tomentose; ovules 2–6, glabrous; lamina ovate, 60–70 mm long, 50–60 mm wide, deeply pectinate, with 20–22 soft lateral spines 30–40 mm long, 1.5–2 mm wide, apical spine distinct or not distinct from lateral spines, 30–40 mm long, 3–4 mm wide at base. *Seeds* flattened-ovoid, 25 mm long, 21 mm wide; sarcotesta yellow, not pruinose, 2 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: although known for several decades, this remarkable species was only recognised as distinct and published in 1994 by Chinese botanist C.J. Chen.

Distinguishing features: the bipinnate leaves immediately distinguish this species and the closely related *C. debaoensis* within the genus. *C. multipinnata* is distinguished from the latter by the longer leaves with broader, thinner leaflets that are broadest above the mid-point, and the smaller megasporophylls with a smaller apical lamina. The subterranean habit, the small, soft microsporangiate cones, the loose, freely peeling sarcotesta lacking a fibrous layer and the verrucose sclerotesta are features shared by a wider group of related species (Section *Stangerioides*).

Distribution and habitat: known from several quite widely disjunct populations, a limited area in the Red River gorge in eastern Yunnan, with a disjunct occurrence in Yen Bai Province, northern Vietnam aand another in western Guangxi in China (Fig. 4). In all occurrences it is found growing in closed evergreen forest on limestone on very steep slopes. Much of the forest habitat has been cleared or severely degraded. Putative hybrids with *C. bifida* are discussed above.

Conservation status: this species is already severely depleted in the Chinese population on the Red River and potentially at risk from horticultural collectors. It is regarded as endangered, although further study of the Vietnamese and Guanxi occurrences is essential. Ver 3.1:IUCN (2001) status is **EN** (Donaldson 2003).

Selected specimens examined: VIETNAM: Yen Bai: Yen Binh, Phuc Ninh, village no. 4, Chang Re mountain, *Hiep 4113 & Hill*, 14 Jan 2000 (HN, NSW). **CHINA: Yunnan:** Gejiu county, Manhao, *Lindstrom s.n.* (NSW, HN); Hekou county, Lianhuatang to Makayihe, on the border of Hekou and Gejue (Manhao), *Chen, Hong, Hill & Stevenson 9, 10 (Hong 348, 349)*, 6 Jul 2000 (PE, YAF, IBSC, NSW, NY);

18. *Cycas debaoensis* Y.C.Zhong & C.J.Chen, Acta Phytotax. Sin. 35(6): 571 (1997).

Type: China, Guangxi, Debao, 106°14'E 23°30'N, 27 Aug 1997, Y.C. Zhong 8762 (holo PE, iso GXF).

Etymology: from the county of Debao in western Guangxi province, with the Latin termination -ensis, place of origin.

Stems acaulescent, 15–20 cm diam. at narrowest point; 3–15 leaves in crown. *Leaves* deep green, semiglossy, 250–300 cm long, moderately keeled (opposing leaflets inserted at 80° on rachis), with 30–50 leaflets, with white tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 80–150 cm long (30–50% of total leaf), petiole glabrous, spinescent for 100% of length; basal leaflets not gradually reducing to spines, 130–170 mm long; spines 1–4 mm long. *Median leaflets* pinnately divided, then dichotomously branched towards the tip, strongly discolorous, 500–560 mm long, 7–11 mm wide, inserted at 75–80° to rachis, not decurrent, narrowed to 2–3 mm at base, (to 27–29% of maximum width), 40 mm apart on rachis, inserted parallel to rachis; section flat; margins flat; apex acute, not spinescent; midrib raised above, flat below. *Cataphylls* narrowly triangular, soft, pilose, 70–90 mm long. *Pollen cones* fusiform, cream, 20–30 cm long, 5–7 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, apex level or raised, apical spine absent. *Megasporophylls* 12–14 cm long, brown-tomentose; ovules 2–6, glabrous; lamina orbicular or ovate, 80–90 mm long, 80–90 mm wide, deeply pectinate, with 26–28 soft lateral spines 40–50 mm long, 2 mm wide, apical spine distinct or not distinct from lateral spines, 30–40 mm long, 3–4 mm wide at base. *Seeds* ovoid, 25–27 mm long, 20–22 mm wide; sarcotesta yellow, not pruinose, 2 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: this remarkable species was only discovered in 1996 and described in

1997 by Chinese botanists C.J. Chen and Y.C. Zhong.

Distinguishing features: the bipinnate leaves immediately distinguish this species and the closely related *C. multipinnata* within the genus. *C. debaoensis* is distinguished from the latter by the shorter and more numerous leaves with narrower, thicker leaflets that are broadest below the mid-point, and the usually longer megasporophylls with a larger lamina. The subterranean habit, the small, soft microsporangiate cones, the loose, freely peeling sarcotesta lacking a fibrous layer and the verrucose sclerotesta are features shared by a wider group of related species (Section *Stangerioides*).

Distribution and habitat: known from two populations in a limited area Debao and Napo Counties in western Guangxi (Fig. 4), growing in mixed evergreen and deciduous woodland on limestone on slopes. Most of the forest habitat has been cleared or severely degraded.

Conservation status: this species is already severely depleted, and potentially at risk from horticultural collectors. It is regarded as critically endangered. Ver 3.1:IUCN (2001) status is **CR** (Donaldson 2003).

Selected specimens examined: CHINA: Guangxi: Debao county, Guangxi province,

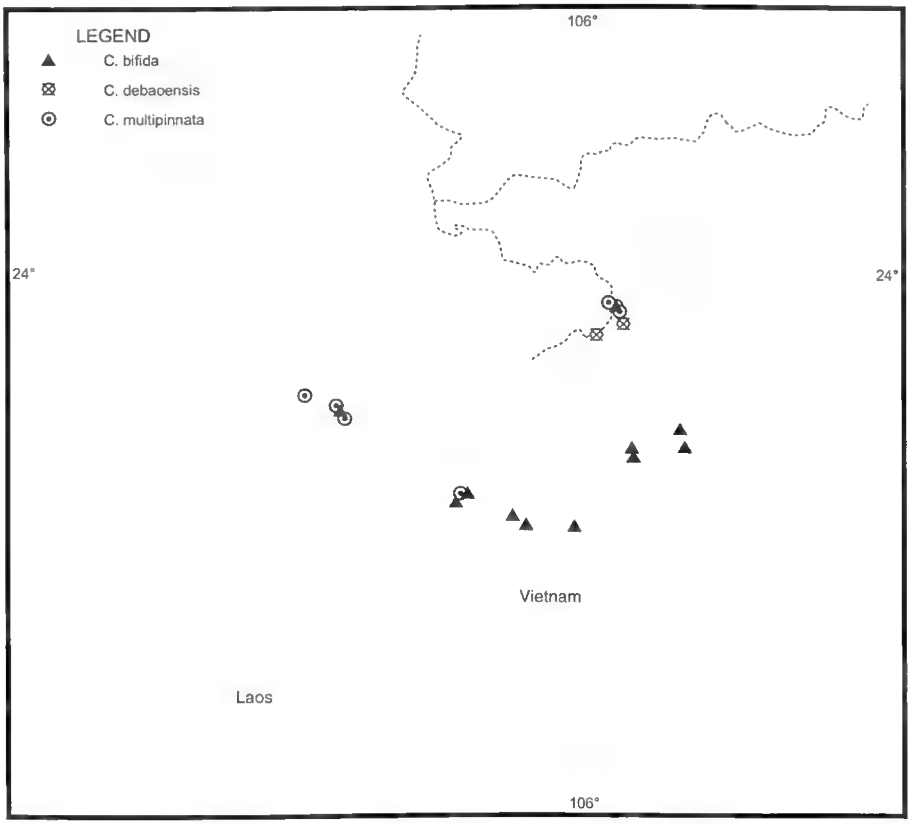

Fig. 4. Distributions of *Cycas debaoensis, C. bifida* and *C. multipinnata.*

Chen, Zhong & Hill 06, 8 Nov 1998 (NSW, BM, FTG, HN, K, KL, L, MO, NY, P, PE)

19. *Cycas ferruginea* F.N.Wei, Guihaia 14: 300 (1994)

Type: cultivated, Guilin Botanical Garden, thought to be introduced from Longzhou County, Guanxi, China, *F.N. Wei 2220*, 31 Aug. 1994 (holo IBK).

Literature: Wang (1996, as *C. miquelii*); Chen and Stevenson (1999).

Illustrations: Wei (1994).

Etymology: from the Latin *ferruginea* rusty red, from the abundant deep red tomentum on new growth and persisting to some extent on the older leaves.

Stems arborescent or acaulescent, to 1.2 m tall, 12–18 cm diam. at narrowest point, 10–25 leaves in crown. *Leaves* deep green or grey-green, highly glossy or semiglossy, 130–210 cm long, slightly keeled or flat (not keeled) in section (opposing leaflets inserted at 150–180° on rachis), with 120–200 leaflets, with white or orange or brown tomentum shedding as leaf expands or persistent below; rachis usually terminated by paired leaflets; petiole 35–80 cm long (25–40% of total leaf), glabrous or pubescent, spinescent for 30–100% of length; basal leaflets not gradually reducing to spines, 80–190 mm long; spines 1–3 mm long. *Median leaflets* simple (often falcate), strongly discolorous, 190–380 mm long, 8–13 mm wide, inserted at 70–90° to rachis, decurrent for 4–8 mm, narrowed to 2.5–4 mm at base (to 25–40% of maximum width), 10–19 mm apart on rachis, inserted parallel to rachis; section slightly keeled; margins recurved; apex acute, spinescent; midrib raised above, flat below. *Cataphylls* narrowly triangular, pungent, pilose, 90–120 mm long. *Pollen cones* fusiform, orange, 25–45 cm long, 4–6 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 16–20 mm long, 9–13 mm wide, fertile zone 15–18 mm long, sterile apex 3–5 mm long, raised, apical spine rudimentary, sharply upturned, 0–3 mm long, or absent. *Megasporophylls* 11–19 cm long, brown-tomentose; ovules 2–6, glabrous; lamina orbicular, 70–110 mm long, 50–80 mm wide, deeply pectinate, with 28–42 soft lateral spines 18–40 mm long, 1–3 mm wide, apical spine distinct from lateral spines, 15–50 mm long, 3–8 mm wide at base. *Seeds* ovoid, 19–24 mm long, 15–21 mm wide; sarcotesta yellow, not pruinose, 1–2 mm thick; fibrous layer absent; sclerotesta verrucose; spongy endocarp absent.

Historical notes: described by Chinese botanist Wei Fan-Nan in 1994, from a single plant in cultivation in Guilin. The wild source was not known at the time, making the origin something of a mystery. Field studies in Vietnam in 1997 discovered large populations of a cycad that appears to match the type plant in Lang Son province. Wild plants have also since been discovered in Tiandong County, western Guangxi Province in China.

Distinguishing features: closely allied to *C. sexseminifera*, but immediately distinguished by the dense dark ferruginous tomentum on new growth, the longer leaves and the longer often falcate leaflets with recurved margins. It also differs in the generally larger proportions in all respects, and the larger and broader megasporophyll lamina. The small, soft microsporangiate cones, the loose, freely peeling sarcotesta lacking a fibrous layer and the verrucose sclerotesta are features shared by a wider group of related species (Section *Stangerioides*).

Distribution and habitat: a restricted species, known from limestone bluffs in western Guangxi Province in China, and also in Lang Son and Thai Nguyen provinces in

Vietnam (Fig. 5). This species shows the same habitat preference as *C. sexseminifera* and *C. tropophylla*, growing on bare limestone faces on steep limestone bluffs, with no visible soil at the roots.

Conservation status: Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003).

Selected specimens examined: CHINA: Guangxi: cultivated, Guilin Institute of Botany (type plant), 28 Nov 1998, *Chen, Zhong & Hill 43* (NSW, PE); Tiandong county, Zuodeng town, 280 m, rocky crevices in limestone mountain, *Chen & Li T2001 – 01, 02, 03,* 26 Apr 2001 (PE, NSW, NY, SZG); *Zhong s.n.*, 2 Feb 1999 (PE, NSW, NY). **VIETNAM: Lang Son:** Huu Lien Nature Reserve, near border post, Huu Lung district, 10 May 1998, *Hill 4995, 4996, 4997,* 4998 & Loc (NSW, HN K NY PE BKF L P MO CANB); Huu Lien Nature Reserve, near village, Huu Lung district, 11 May 1998, *Hill 5000, 5001, 5002 & Loc* (NSW, HN K NY PE BKF L P MO CANB); Huu Lung, Huu Lien, Apr 1998, *Hiep 2410, 2411, 2412* (HN). **Thai Nguyen:** Dong Hy, Quang Son cult in garden, coll from steep limestone cliffs 3–400 m to W, 16 Mar 1999, *Hill 5043 5044 & Loc* (HN, NSW); Vo Nhai, La Hien, 20 km NE of Thai Nguyen city, 28 Mar 1996, *Yang & Hiep 766* (HN).

20. *Cycas sexseminifera* F.N.Wei, Guihaia 16: 1 (1996).

Type: cultivated, Guilin Botanical Garden, introduced from Longzhou County, Guangxi, China, *F.N. Wei 2223*, 1994 (holo IBK).

Cycas acuminatissima Hung T.Chang, Y.C.Zhong & Z.F.Lu, Acta Sci. Nat. Univ. Sunyatseni 37(4): 6 (1998).

Type: China, Guangxi, Tianyang, *Y.C. Zhong 8770*, 26 Mar 1998 (holo SYS n.v.). Included in the synonymy of *C. segmentifida* by Chen and Stevennson (1999), but the type collection is from within the range of *C. sexseminifera* and away from the range of *C. segmentifida*. The illustration accompanying the protologue also matches *C. sexseminifera*, and this taxon is here included in the synonymy of that species. Field studies in the type locality also do not substantiate the presence of another taxon.

Cycas brevipinnata Hung T.Chang, Y.Yuan Huang &Y.C.Zhong, Acta Sci. Nat. Univ. Sunyatseni 37(4): 8 (1998).

Type: cultivated Nanning arboretum Guangxi, China, *H.X. Zheng & Y.Y. Huang 98003*, 21 Apr 1998 (holo SYS n.v.). Included in the synonymy of their concept of *C. miquelii* by Chen and Stevenson (1999), and in *C. sexseminifera* by Chen and Liu (2004).

Cycas longisporophylla F.N.Wei, Guihaia 17: 209 (1997).

Type: cultivated, Guilin Botanical Garden, introduced from Longzhou County, Guangxi, China, *F.N. Wei 2222*, 19 Jun 1995 (holo IBK). Included in the synonymy of their concept of *C. miquelii* by Chen and Stevenson (1999), and in *C. sexseminifera* by Chen and Liu (2004).

Cycas septemsperma Hung T.Chang, Y.Yuan Huang & H.X.Zheng, Acta Sci. Nat. Univ. Sunyatseni 37(4): 8 (1998).

Type: cultivated Nanning arboretum Guangxi, China, *Y.Y. Huang & H.X. Zheng 192*, Aug 1998 (holo SYS n.v.). Included in the synonymy of their concept of *C. miquelii* by Chen and Stevenson (1999), and in *C. sexseminifera* by Chen and Liu (2004).

Cycas spiniformis J.Y.Liang, in F.N.Wei, Guihaia 17: 211 (1997).

Type: cultivated, Guilin Botanical Garden, introduced from Longzhou County, Guangxi, *F.N. Wei 2266*, 16 Sep 1995 (holo IBK). Included in the synonymy of their concept of *C. miquelii* by Chen and Stevenson (1999), and in *C. sexseminifera* by Chen and Liu (2004).

Cycas crassipes Hung T.Chang, Y.C.Zhong & Z.F.Lu, Acta Sci. Nat. Univ. Sunyatseni 38(3): 121–122 (1999).

Type: Guangxi, Longling County, *Y.C. Zhong 8778*, 29 May 1998 (holo SYS n.v.). The type collection is from within the range of *C. sexseminifera.* The illustration accompanying the protologue matches *C. sexseminifera*, and this taxon is here included in the synonymy of that species. Field studies in the type locality also do not substantiate the presence of another taxon.

Cycas miquelii non Warb., sensu Wang (1996), De Laubenfels and Adema (1998, in part), Chen and Stevenson (1999), see below.

Literature: Wang (1996, as *C. miquelii)*, Chen and Stevenson (1999, as *C. miquelii*).

Illustrations: Wang (1996, as *C. miquelii*).

Etymology: from the latin *sex*, six, and *seminifera*, seed-bearing, in the misplaced belief that the six seeds observed on the megasporophyll of the type plant was a diagnostic distinction.

Stems arborescent or acaulescent, to 0–1 m tall, 8–20 cm diam., 4–20 leaves in crown. *Leaves* deep green, semiglossy, slightly keeled to flat (not keeled) in section (opposing leaflets inserted at 150–180° on rachis), with 80–200 leaflets 50–120 cm long, with brown tomentum shedding as leaf expands;rachis consistently terminated by paired leaflets petiole 10–40 cm long (20–35% of total leaf), glabrous, unarmed or spinescent for 5–100% of length; basal leaflets not gradually reducing to spines, 10–80 mm long; spines 1–3 mm long. *Median leaflets* simple, strongly discolorous, 130–240 mm long, 6–10 mm wide, inserted at 70–85° to rachis, decurrent for 2–6 mm, narrowed to 2–5.5 mm at base (to 25–55% of maximum width), 8–14 mm apart on rachis, section slightly keeled, margins flat or slightly recurved; apex aristate, spinescent; midrib raised above, raised below. *Cataphylls* narrowly triangular, soft, pilose, 30–50 mm long. *Pollen cones* narrowly ovoid to fusiform, yellow, 15–30 cm long, 5–8 cm diam.; microsporophyll lamina soft, not dorsiventrally thickened, 20–30 mm long, 12–30 mm wide, fertile zone 10–28 mm long, sterile apex 2–4 mm long, raised, apical spine rudimentary or absent, sharply upturned, 0–3 mm long. *Megasporophylls* 8–12 cm long, brown-tomentose; ovules 2–6, glabrous; lamina orbicular, 35–55 mm long, 30–50 mm wide, deeply pectinate, with 16–28 soft lateral spines 10–25 mm long; apical spine distinct from lateral spines, 30–40 mm long. *Seeds* ovoid, 20–28 mm long, 18–25 mm wide; sarcotesta yellow, not pruinose; fibrous layer absent; sclerotesta smooth to verrucose; spongy layer absent.

Historical notes: Metcalf (1942) applied the name *C. inermis* to this species. Later treatments from China (Cheng et al. 1975, Zhou et al. 1990) also confused it with *C. pectinata* (which does occur in China, but considerably to the west of this species). Occurrences in Vietnam were overlooked by Leandri (1931), Ho (1960, 1991) and Hiep and Vidal (1996). Wang (1996) and Chen and Stevenson (1999) applied the name *C. miquelii* to this species (see above under *C. revoluta* for extra comment on *C. miquelii*). The treatment under the name *C. miquelii* by de Laubenfels and Adema (1998) presents a confused concept that includes *C. sexseminifera* and other taxa. Their neotypification of the name *C. miquelii* is based on a specimen of a quite different species, *C. clivicola* from southern Thailand.

Distinguishing features: this species is most readily distinguished by the dwarf habit with a short stem and short, flat leaves with short, narrow, flat, rather stiff and pungent leaflets, and the small but broad megasporophyll lamina with a broad apical spine distinct from the lateral spines; petioles are often unarmed (hence the misapplication of the epithet "inermis"), but this character is not at all consistent. The small, soft microsporangiate cones, the loose, freely peeling sarcotesta lacking a fibrous layer and the verrucose sclerotesta are features shared by a wider group of related species (Section *Stangerioides*).

Distribution and habitat: widespread in southern and central Guangxi province of China, and in a limited area in Cao Bang province in central northern Vietnam in the border region with Guangxi, with a disjunct occurrence in Thanh Hoa province south of Hanoi (Fig. 5). Locally abundant, growing in crevices in bare outcrops in rugged karst limestone country, often on vertical faces with no visible soil.

Conservation status: although there is a clear demand for this species in horticultural markets in China and Vietnam, and a substantial collection from the wild for this trade, this species is extremely abundant in many inaccessible sites. Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003).

Selected specimens examined: CHINA: Guangxi: Longzhou county, Long Gan natural reserve, 21 Nov 1998, *Chen, Zhong & Hill 31, 32* (NSW, PE), *Chen, Zhong & Hill 33* (NSW, PE); cult., nursery of Nanning Forestry Research Centre, Nanning, collected from southern Guangxi (same collection as type plant of *Cycas brevipinnata*, separate plant), 7 Nov 1998, *Chen, Zhong & Hill 2* (NSW, P, PE); cult. Qing Xui Wu park, Nanning, collected from southern Guangxi, 7 Nov 1998, *Chen, Zhong & Hill 5* (NSW, PE); cult. Longzhou city park, collected nearby, 21 Nov 1998, *Chen, Zhong & Hill 34, 35* (NSW, PE). **VIETNAM: Cao Bang:** Thach An, Thuy Hung, 1 Dec 1996, *Averyanov et al. CBL912* (HN), 4 Dec 1996, *Averyanov et al. CBL878* (HN); Quang Hoa, Quoc Phong, Lung Trang, 14 Mar 1999, *Hill 5031 & Loc* (HN, NSW). **Ninh Binh:** Nho Quan, Cuc Phuong, Nga village, outside entrance to Cuc Phuong National Park, cult in garden, coll. on hill behind village, 19 Mar 1999, *Hill 5053 & Loc* (HN, NSW); Bich Dong, 25 Oct 1994, *Yang & Hiep SLY526* (HN). **Thanh Hoa:** Nhu Xuan, Ben En National Park, 21 Oct 1996, *Hiep 2114* (HN), 30 Mar 1996, *Loc P7063* (HN).

D. Section **INDOSINENSES** J.Schust.

Cycas section *Indosinenses* J.Schust., Pflanzenr. 99: 65 (1932).

Lectotype (fide Hill & Yang 1998): *C. siamensis* Miq. This is one of only two species included in this section by Schuster, and the single species remaining when the other species (*C. micholitzii*) is removed to section *Stangerioides*, as was done by Smitinand (1971).

Section *Indosinenses* is defined by the combination of stiff or woody male cones, glabrous ovules, a large, deeply pectinate megasporophyll lamina, and the presence of a layer of fibrous tissue within the sarcotesta. It is a taxonomically complex group ranging from Himalayan India and Nepal east to Vietnam and southern China and south to northern peninsular Malaysia. Sectional circumscription herein follows Wang (1996). Two species occur in China (Figs. 1, 6).

21. *Cycas pectinata* Buch.-Ham., Mem. Wern. Nat. Hist. Soc. 5(2): 322–323 (1826). *Cycas circinalis* subsp. *vera* var. *pectinata* (Griff.) Schuster, Pflanzenr. 99: 68 (1932).

Neotype: India, E. Bengal, Chittagong, *J.D. Hooker & Thompson 6*, 1855 (K: isoneo P).

De Laubenfels and Adema (1998) designated this specimen as lectotype but this was an error since the specimen was collected after the name was published. This error is correctible under ICBN Art. 9.8 and they are deemed to have neotypified it.

Cycas jenkinsiana Griff., Not. Pl. Asiat. 4: 9–10, Plates 360, fig. 1–2 and 362, fig. 1 (1854).

Type: India, Assam, *Jenkins s.n.* (holo K; iso BM, L). Included in the synonymy of *C. pectinata* by Smitinand (1971).

Literature: Chen and Stevenson (1999).

Illustrations: Smitinand (1971), Cheng et al. (1975), Grierson and Long (1983), Wang (1996), Tang et al. (1997), Hill and Yang (1998).

Etymology: from the Latin *pectina*, a comb, in reference to the long, comb-like teeth of the megasporophylls.

Vernacular: Assam - *thaljimura*; Burmese - *môndaing*; Chinese - *bi-chi su-tie* (cycad with comb-like megasporophylls), *feng-wei-jiao* (Phoenix-tail grass or palm), *feng-huang-dan*, Khasi - *dieng-sia-goda*; Nepalese - *thakal, thaljimura*; Thai - *boka, plong, prong khao, prong pa* (forest or field cycad) (Chen et al. 1995, Hill & Vatcharakorn 1998,

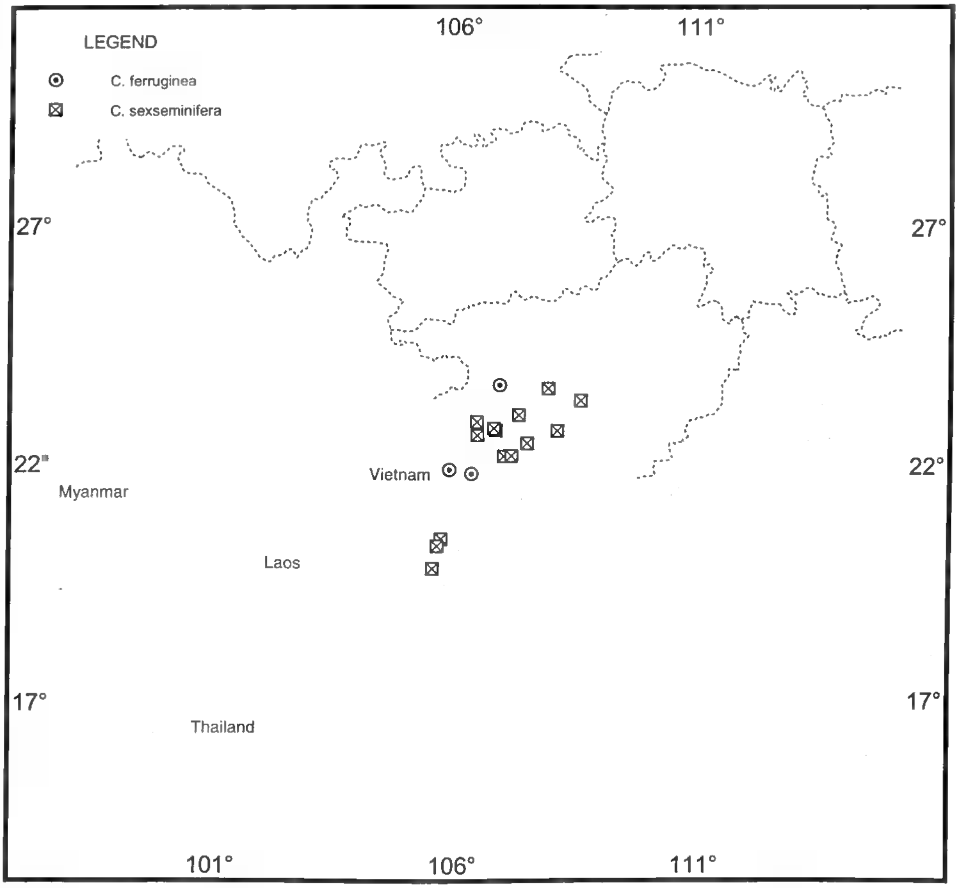

Fig. 5. Distributions of *Cycas sexseminifera* and *C. ferruginea.*

Pant 1962, Pant et al. 1994, Smitinand 1972, Walters & Yang 1994, Bonta & Osborne 2007).

Stems arborescent, to 1–12 m tall, 14–20 cm diam., 30–40 leaves in crown. *Leaves* deep green to grey-green, semiglossy, 150–240 cm long, with white tomentum shedding as leaf expands, flat (not keeled) in section (opposing leaflets inserted at 170–180° on rachis), with 180–312 leaflets, rachis consistently terminated by a spine 1–46 mm long; petiole 30–80 cm long (25–50% of total leaf), glabrous, spinescent for 30–80% of length; basal leaflets not gradually reducing to spines, 50–160 mm long; spines 1–4 mm long. *Median leaflets* simple, strongly discolorous, 200–315 mm long, 7.5–10.5 mm wide, inserted at 45–60° to rachis, decurrent for 4–8 mm, narrowed to 2.5–4 mm at base (to 35–45% of maximum width), 8–13 mm apart on rachis, section flat, margins slightly recurved; apex acute, spinescent to not spinescent; midrib raised above, raised below. *Cataphylls* narrowly triangular, soft, pilose. *Pollen cones* ovoid, yellow or green, 30–55 cm long, 16–22 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, 43–60 mm long, 19–24 mm wide, fertile zone 35–57 mm long, sterile apex 3–8 mm long, level, apical spine prominent, sharply upturned, 17–32 mm long. *Megasporophylls* 22–30 cm long, grey-tomentose; ovules 2–4, glabrous; lamina orbicular, 110–180 mm long, 100–130 mm wide, deeply pectinate, with 40–50 soft lateral spines 26–75 mm long, 2–3 mm wide; apical spine distinct from lateral spines, 35–75 mm long, 5–12 mm wide at base. *Seeds* flattened-ovoid, 42–45 mm long, 33–45 mm wide; sarcotesta yellow, not pruinose, 4–7 mm thick; fibrous layer present; sclerotesta smooth; spongy layer absent.

Historical notes: *C. pectinata* was the fourth species of *Cycas* to be named, described in 1826 by Scottish surgeon and botanist Francis Buchanan-Hamilton. No type was cited, but reference was made to occurrence in 'the hills which bound Bengal to the east', and the description cited 'Habitat in Camrupae orientalis sylvis'. *C. angulata* R. Brown and *Olus calappoides* of Rumphius (*C. rumphii*) were cited (erroneously) in synonymy. Zhou et al. (1990) regarded Hamilton's publication as illegitimate because *C. angulata* was cited as a synonym. The latter was cited, but with a question mark, indicating that the author was unsure of the placement of *C. angulata*. This does not invalidate Hamilton's publication (ICBN Art. 52.2, Note 1, Ex. 12). The primary set of Hamilton's Bengal collections eventually went to Wallich and thence to Kew (K-W). A second set went to E. Neither set includes a specimen that could be regarded as the type of *C. pectinata*.

The name *C. pectinata* has been incorrectly attributed to Griffith (1854) by numerous authors eg. Miquel (1868), Thistleton-Dyer (1888), Warburg 1900, Smitinand (1972), de Laubenfels (1988), but he was only giving a description of the species, not formally describing it. Griffith did not add his name to the binomial, which was his usual practice with existing or previously published names.

Distinguishing features: the very large, ovoid microsporangiate cones with long, narrow microsporophylls, those with long apical spines, readily distinguish this species from others in the *C. pectinata* group. The thin, smooth bark also distinguishes this species from related taxa, although this feature is shared with *C. clivicola* and *C. elongata*, and seems to be an artifact of the occurrence in wetter forests, where the usual armour of leaf bases and cataphylls is quickly removed by the general processes of decomposion in the moister environment.

Distribution and habitat: common and widespread in forest on hills of the central highlands, mostly above about 500 m altitude (Fig. 6). This species occurs in medium to tall forest on deep, often clay-rich and more fertile soils, usually as part of the general shrub understorey at medium to higher elevations in generally moist conditions in moderate to deep shade. Although often found on limestone substrates, it is by no means restricted to these, and also occurs on granites and metasediments.

C. pectinata is abundant in the hill forests in parts of north-eastern India, and has also been collected from Nepal and Bhutan. It extends into Yunnan Province in southern China, often on soil over limestone, and east into Thailand, Laos and Vietnam.

Conservation status: a very widespread species. Although its habitat is continually being reduced, large populations remain, and it is not under any immediate threat of extinction. Ver 3.1:IUCN (2001) status is **VU** (Donaldson 2003). The status is determined on the basis of the continuing population decline, although the very large populations remaining indicate that the short-term threat of extinction is low.

Selected specimens examined: CHINA: Yunnan, *Henry 13637* (K, NY); Meng Yuan district, Meng La Natural Reserve, *Lindstrom s.n.*, 1994 (no voucher); Simao County, *Mao Pymao 6109*, 20 Sep 1955 (KUN); Jinghong County, Na Bai, *Tao 43719*, 21 Oct 1988 (XBG). **BANGLADESH:** Chittagong, *Hooker & Thompson Herb. Ind. Or* (BM, K, L); Satakoina, Chittagong, *Hooker & Thompson 595*, 11 Jan 1857 (K). **BHUTAN:** E bank of Dangme Chu, between Cha Zam and

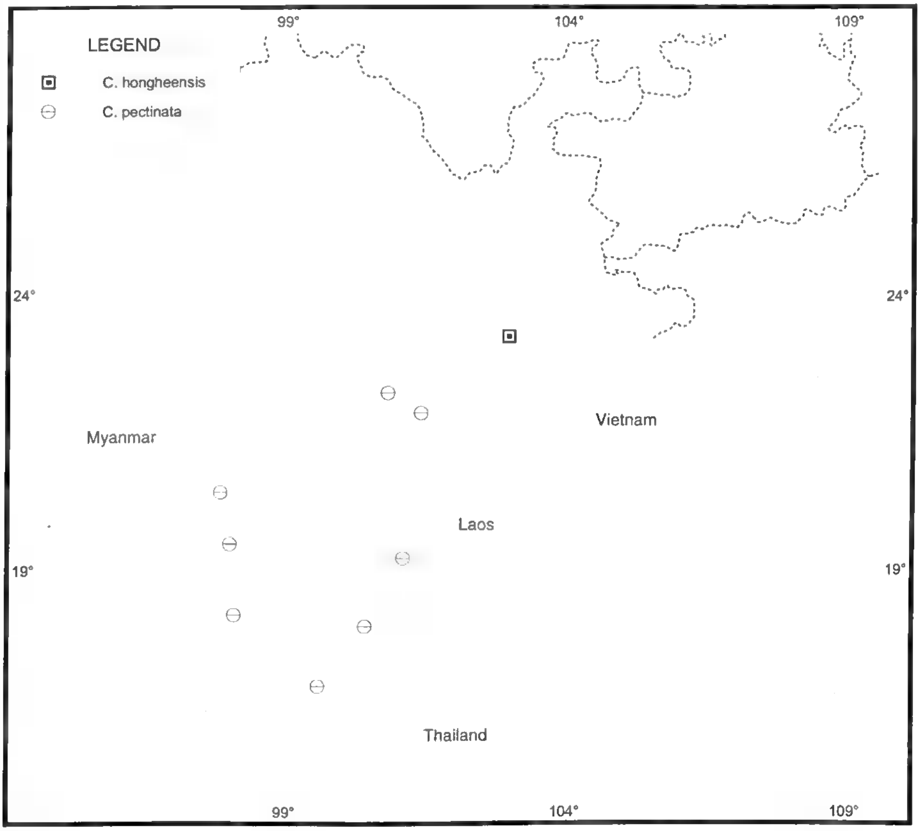

Fig. 6. Distributions of *Cycas pectinata* and *C. hongheensis.*

Duksun, N of Tashigang, *Grierson & Long 2357*, 29 Jun 1979 (K ex E). **INDIA:** Gowatty, *Clark 43243*, 29 Mar 1886 (K); Satte Bhaia Jhai, Darij Serai, *Gamble 2675A*, Jan 1875 (K); Rammagar Hills, *Haines 3983*, Nov 1916 (K); Great Rungeet Valley, Sikkim, *Hooker s.n.*, 1848 (K); Khasia, *Hooker & Thompson*, 16 Jul 1850 (K); Laki, Lakhei County, Lushai Hills, Assam, *Parry 100*, Feb 1927 (K); Koongi Valley, Manipur, *Watt 6796*, 27 Apr 1882 (K). **MYANMAR:** Shan States, *Aplin s.n.*, Nov–Dec 1887 (K); Mundat, *Kingdon Ward 22308*, 18 May 1956 (K); Rangoon, *Meebold 8166*, Jan 1908 (K). **NEPAL:** Mechizou Jhapa district, *Nicolson 3078*, 31 Mar 1967 (BM); Ganjbari (26°45'N 87° 58'E), *Stainton 5733*, 1 Apr 1967 (BM); Udaipur Ganhi (26°56'N 86°31'E), *Stainton 6638*, 3 Nov 1969 (BM). **THAILAND: Chaiyaphum**: near Chulaphorn Dam, *Larsen, Supee, Larsen, Nielsen & Santisuk 31432*, 5 Aug 1972 (BKF). **Chiang Mai**: Doi Pha Hom Pok, Fang, *Kerr 5218*, 3 Apr 1921 (BM, K). **Kanchanaburi**: Ban Huay Sue, E of Thong Pha Phum, *Hill 4645*, 02 May 1994 (NSW, BKF, K, L, PE). **Loei**: Phu Paek, *van Beusekom & Phengklai 3027*, 14 Jan 1970 (L ex BKF). **Mae Hong Son**: Ban Mok Jum Prak, *Hill 4638*, 26 Apr 1994 (NSW). **Phetchabun**: N of Chai Badun, *Abbe, Abbe & Smitinand 9361 B*, 2 Jan 1960 (BKF). **Phrae**: Mae Kating, *Williams & Smitinand 17133* (BKF). **Sukhothai**: Khao Luang, *Kerr 5944*, 4 May 1922 (BM, K). **VIETNAM: Gia Lai:** Tu An, Tu Thuy, between An Khe and Kbang, 30 Oct 1994, *Yang 531, Ban & Lindstrom* (HN); Kbang, 30 Oct 1994, *Yang 532, Ban & Lindstrom* (HN). **Kon Tum:** between Dak Poko and Dak Mek rivers, 1000 m alt, 28 Mar 1995, *US Nat. Geog. Soc. Exped. VH 962, 963* (HN); Dak Poko River near Dak Gley township, 600 m alt, 29 Mar 1995, *US Nat. Geog. Soc. Exped. VH 1017, 1018* (HN); along Dak Poko River 6 km N of Dak Gley township, 6–700 m alt, 16 Apr 1995, *US Nat. Geog. Soc. Exped. VH 1385–1387* (HN), 28 Nov 1995, *VH 2078* (HN), 29 Nov 1995, *VH 2145–6* (HN). **Lam Dong:** Dalat, 5 Nov 1994, *Yang 542, 543, Ban & Lindstrom* (HN). **Quang Ngai:** Duc Pho, Pho Khanh, 25 Jan 2000, *Hiep 4162, 4163, 4164 & Hill* (HN, NSW).

22. *Cycas hongheensis* S.Y.Yang & S.L.Yang, in D.Y.Wang, Cycads China: 62 (1996).

Type: Yunnan, Gejiu, *S.Y. Yang 9301*, 17 May 1993 (holo Panzhihua Inst. Hort.; iso FTG, HWA, PE).

Literature: Walters & Yang (1994), Yang & Pu (1994), Yang & Yang (1994)

Illustrations: Yang & Yang (1994), Wang (1996).

Etymology: from Hong-he (the Red River), near the habitat in south-eastern Yunnan, with the Latin suffix *-ensis*, place of origin.

Vernacular: Chinese - *ba-he su-tie, hong-he su-tie* (Walters & Yang 1994, Bonta & Osborne 2007).

Stems arborescent, to 1–3 m tall, 12–15 cm diam. at narrowest point; 12–25 leaves in crown. *Leaves* grey-green, dull, 70–100 cm long, strongly to moderately keeled (opposing leaflets inserted at 80–120° on rachis), with 120–140 leaflets, with white tomentum persistent above and below; rachis usually terminated by a spine 5 mm long; petiole c. 26 cm long (30% of total leaf), petiole pubescent, spinescent for 100% of length; basal leaflets not gradually reducing to spines, 95 mm long; spines 1–3 mm long. *Median leaflets* simple, strongly discolorous, 150–200 mm long, 7–8 mm wide, inserted at 50° to rachis, decurrent for 4 mm, narrowed to 4.5 mm at base (to 60% of maximum width), 10 mm apart on rachis; section slightly keeled; margins slightly recurved to recurved; apex acute, not spinescent; midrib flat above or raised above (slightly), raised below. *Cataphylls* narrowly triangular, pungent, thinly sericeous or lacking tomentum, 35–50 mm long. *Cones* not seen.

Historical notes: this member of the *C. pectinata* group was first discovered and noted as a distinct taxon by Chinese botanists in 1993 (Wang 1996), although no reproductive material was seen. It was finally described in 1996, still in the absence of reproductive material, although seeds were reported by local people to be large.

Distinguishing features: the tall, smooth trunk is quite similar to that of *C. pectinata* and related species from Thailand. The keeled leaves with a moderately persistent white tomentum distinguish it immediately from all other species in the *C. pectinata* group.

Distribution and habitat: known only from a limited area along the Hong He River in Gejiu County (Fig. 6). Once locally common in dense scrub on steep limestone outcrops at lower elevations, but now severely depleted by collecting for sale as an ornamental plant. Plants are in low open vine thickets, often with succulent *Euphorbia* species, and most often rooted in clefts and crevices, often with little no soil at the roots. This species is apparently endemic to these seasonally dry limestone outcrops.

Conservation status: 1997 IUCN Red List of Threatened Plants (Water & Gillett 1998) category E. Ver 3.1:IUCN (2001) status is **CR** (Donaldson 2003).

Selected specimens examined: CHINA: Yunnan: Baohe town, Gejiu county, in dry side valley to north off Hong He valley, on limestone, heavily cut and damaged, *Chen, Jiang, Hill & Stevenson 018*, 8 Jul 2000 (PE, NSW, NY, YAF).

Excluded names

Cycas longipetiolula D.Y. Wang, Cycads China: 68 (1996). Type: China, Yunnan, Yuanjiang River valley, *D.Y. Wang & H. Peng 5523*, 23 Apr 1994 (holo SZG, iso NF). *Cycas multipinnata* is apparently sympatric with *C. bifida* in several populations in China, and a range of morphologically intermediate forms that can be interpreted as a hybrid swarm has been observed. The type of *C. longipetiolula* is one such form.

Cycas multifrondis D.Y. Wang, Cycads China: 80 (1996). Type: cultivated in Xiamen Botanical Garden, *D.Y. Wang 5024*, 28 Jun 1994 (holo SZG, iso NF).). *Cycas dolichophylla* is apparently sympatric with *C. bifida* in several populations in China, and a range of morphologically intermediate forms that can be interpreted as a hybrid swarm has been observed. The type of *C. multifrondis* is one such form.

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The genus *Cycas* (Cycadaceae) in The Philippines

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Abstract

The genus *Cycas* is reviewed for The Philippines. Ten species are enumerated, with five described as new (***Cycas saxatilis*, *C. aenigma*, *C. vespertilio*, *C. nitida*** and ***C. lacrimans***). C. *wadei*, *C. curranii* and *C. saxatilis* are placed in the new Section ***Wadeae***. Lectotypes are chosen for *Cycas circinalis* subsp. *riuminiana* var. *curranii* forma *graminea* J.Schust. and *Cycas circinalis* subsp. *riuminiana* var. *curranii* forma *maritima* J.Schust. The species are placed within an infrageneric classification previously outlined. Distribution of all taxa is mapped, conservation status is discussed and a key to species provided. Previous recordings of *C. circinalis* and *C. rumphii* from The Philippines are discussed.

Introduction

The genus *Cycas* is the single constituent genus of the family Cycadaceae, itself the basal lineage of the living cycads (Stevenson, 1992). It is also the sole living cycad group occurring in Asia. The only known fossil evidence for this genus is from the Eocene of China and Japan, and this, together with the occurrence of all major lineages in the genus in mainland Asia, supports a long-term presence and probable origin of this genus in that region (Hill 1995). *Cycas* consists of about 100 species, chiefly Indo-Chinese (about 40 species) and Australian (27 species). The genus also occurs in the Malesian region, Japan and India, extending to Micronesia and Polynesia, Madagascar and East Africa. Plants are commonly understorey shrubs in forest, woodland or savanna habitats. Ten species are known in The Philippines.

The cycad flora of The Philippines is relatively sparse in comparison to Indochina and northern Australia, both of which show extensive local radiations. The Philippines is however notable for the occurrence of the endemic relictual section *Wadeae*, which shows links to Mainland Asian groups and has probably been separated by crustal rifting in the early Tertiary.

The present work is the outcome of our separate and combined studies, with a total of three field trips during the period 2000–2007. Herbarium collections held by A, B, BM, BO, E, K, G, L, LAE, LBC, NY, P and SING have been examined by at least one author. Authorship of new taxa is as stated in species descriptions. Terminology is as in previous papers in this series (e.g. Hill 1994), as are generic and specific concepts followed.

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Conventions in measurements taken and presented in the following descriptions are as in other papers in this series, and are set out in Lindstrom and Hill (2007). Nomenclature follows the latest version of the International Code of Botanical Nomenclature [ICBN] (McNeill et al. 2006).

Conservation

Populations of many Asian species appear to have declined, sometimes dramatically, over the past century. However, there is no comparative data to support this impression, and evidence for the decline is largely anecdotal and circumstantial. Several causative factors for this decline can be observed in action today, however, even though quantitative data on the effects are not available. Two principal threats to cycads exist in The Philippines at present: habitat loss and selective removal of plants from the wild for trade or utilization. Some but not all species occur in reserved areas already proclaimed, but enforcement within these areas is sometimes difficult. There is, however, a growing interest in habitat and species conservation within The Philippines, and additional reserved areas are being evaluated and declared.

Another, more uncontrollable threat is the rapid spread of *Aulacaspis* scale insect (Howard et al. 1999). The scale seems to be controlled naturally by native predators on Palawan (*C. curranii*, *C. saxatilis*) and Culion (*C. wadei*) but is seriously affecting large numbers of cultivated cycads on Luzon, Negros and Panay. It has yet to be confirmed if the scale has spread into wild populations but historically known populations of *C. edentata* are now gone and cultivated plants in the near vicinity are dying from the scale. It seems that there is no natural predator in existence on these islands and the spread of the scale into wild populations and further to other islands as yet not affected would be of serious consequences to many endemic Philippine cycads.

Two Philippine species (*C. chamberlainii*, *C. wadei*) were listed in the now out-of-date (for this region) IUCN 1997 Red Book of Threatened Plants (Walter & Gillet 1998). Species treated below are allocated provisional conservation status codes under the new coding system devised by the IUCN (IUCN 2001). Conservation status of all species is summarised in Table 1.

Taxonomic history

The genus *Cycas* was first recorded from The Philippines by Regel (1863), with his description of *C. riuminiana* from cultivated plants imported from Manila. Four Philippine taxa were listed by Merrill (in Foxworthy 1911): *C. circinalis*, *C. revoluta*, *C. sp. aff. cairnsiana* (now *C. wadei*) and C. sp. Palawan (now *C. curranii*). The same four species were listed by Merrill in 1923, but now with the name *C. cairnsiana* incorrectly assigned to the species from Culion. Plants from Mt Arayat in Luzon were described as *C. chamberlainii* in 1925, and the plants from Culion were described as *C. wadei* in 1936.

The next discussion of the cycads of the region was by Zamora and Co (1979), listing four species, *C. revoluta*, *C. circinalis*, *C. wadei* and *C. chamberlainii*. This was followed by Amoroso (1986), with 5 species, *C. revoluta*, *C. circinalis*, *C. wadei*, *C. chamberlainii* and *C. rumphii*. This was the first acknowledgement that a species of the *Cycas rumphii* group was present in the Philippines, and the first clear separation of the two species treated below as *C. riuminiana* (*C. circinalis* sensu Amoroso) and *C. edentata* (*C. rumphii* sensu Amoroso).

Table 1. Conservation status of cycad species in The Philippines.

	Country	1997 Red List Status	Re-served	IUCN Ver 3.1 2001 Status (Donaldson 2003)	Pop. size	Present decline	Range (km²)	Hab. reduct. (%)
C. aenigma	Philippines	-	?	DD#	?	?	?	?
C. curranii	Philippines	-	y	DD, NT#	<5000	stable	<50	<20
C. edentata	Philippines	-	y	DD, NT#	<10000	?mod	~1000	20–50
C. lacrimans	Philippines	-	y	EN#	<5000	?mod	<50	20–50
C. nitida	Philippines	-	y	NT #	<5000	stable	<50	<20
C. riuminiana	Philippines	V*	y	DD, LC#	<10000	?mod	~500	50–80
C. saxatilis	Philippines	-	y	LC#	<5000	stable	<50	<20
C. vespertilo	Philippines	-		NT#	<5000	?mod	<100	20–50
C. wadei	Philippines	E	N	DD, NT#	<5000	stable	<10	<20
C. zambalensis	Philippines	-	?	CR#	<5000	stable	<50	<20

* as ***C. chamberlainii***

\# status recommended by authors

The account by de Laubenfels and Adema (1998) records four species from the Philippines, *C. silvestris*, *C. wadei*, *C. edentata* and *C. riuminiana*. *C. chamberlainii* is included in the synonymy of *C. riuminiana*, and their interpretation of *C. silvestris* (here regarded as an Australian endemic) includes material treated below under *C. curranii*, *C. riuminiana* and *C. edentata*. Only the name *C. wadei* is wholly correctly applied by these authors.

Madulid and Agoo described the endemic *C. zambalensis* in 2005.

Taxonomic treatmant

CYCAS L., Sp. Pl.: 1188 (1753).

Lectotype: *C. circinalis* L.; designated by Stevenson in Jarvis et al. (1993).

Dioecious palm-like shrubs with aerial or subterranean, pachycaul, cylindrical stems clad with persistent frond-bases. Fronds loosely pubescent when young, pinnate, spirally arranged, produced in seasonal growth flushes interspersed with cataphylls, lower pinnae often reduced to spines. Longitudinal ptyxis erect or rarely reflexed, horizontal ptyxis circinate. Pinnae with a single thick midrib and no lateral veins; stomata confined to abaxial surface in most species; individual ptyxis involute. Trichomes microscopically transparent, branched or simple. Leaves with vascular traces girdling stems, girdling traces not present in cataphylls or megasporophlls. Microsporophylls aggregated into determinate cones and bearing numerous microsporangia (pollen-sacs) on abaxial surfaces, with a simple sterile apex, which is often produced into an upturned spine; microsporangia opening by slits; pollen cymbiform, monosulcate. Megasporophylls spirally arranged in an indeterminate terminal rosette with the central axis continuing vegetative growth. Ovules two to many (rarely one), marginally inserted on the stipe and directed obliquely outwards ('ascending'); sporophyll apically dilated into a pinnatifid, pectinate, toothed or entire lamina. Seeds with a yellow, orange or brown fleshy outer sarcotesta, and with or without spongy tissue beneath the inner woody sclerotesta. Endosperm haploid, derived from the female gametophyte. Embryo straight; with 2 cotyledons that are usually united at the tips and a very long, spirally twisted suspensor; seeds platyspermic; germination cryptocotylar.

Six sections are now recognised; four in Hill (1995), an additional one in Hill (2008) and another one in this paper. There has been disagreement on subgeneric division (Wang 1996, de Laubenfels 1998) and, in the light of improved understanding of the genus, none of the proposed systems would appear entirely adequate (Hill 1998, 2004a, Hill 2004b). Two clear groups, regarded below as sections, occur naturally in The Philippines, and a third is represented by one widely cultivated species.

Key to sections

1 Ovules tomentose .... Section #*Asiorientales*

1* Ovules glabrous

  2 Male sporophylls soft & waxy, lacking an upturned apical spine; seeds with a pronounced longitudinal ribbing.. Section *Wadeae*

  2* Male sporophylls hard, with a distinct apical spine; seeds smooth .... Section *Cycas*

Key to species

1 Ovules and seeds tomentose; leaflet margins strongly recurved .... #*C. revoluta*

1* Ovules and seeds glabrous; leaflet margins not strongly recurved

  2 Male cones soft, waxy; sclerotesta strongly ribbed

    3 Seeds small; < 40 mm long

      4 Leaflets 3–8 mm wide .... 1. *C. wadei*

      4* Leaflets 10–14 mm wide .... 3. *C. saxatilis*

    3* Seeds large; ≥ 40 mm long .... 2. *C. curranii*

  2* Male cones firm; sclerotesta not ornamented

    5 Lateral spines on megasporophylls distinct

      6 Apical lamina of megasporophyll < 80 mm long

        7 Leaflets stiff, narrow (5–8 mm wide), leaves keeled, petiole tomentose .... 8. *C. zambalensis*

        7* Leaflets wider (> 7 mm), lax, leaves flat, petiole not tomentose

          8 Megasporophyll with 2 broad wing-like lateral processes .... 6. *C. vespertilio*

          8* Megasporophyll with more than 8 lateral spines

            9 Littoral species, thick spongy endotesta present .... 10. *C. nitida*

            9* Inland forest species, spongy endotesta absent or thin

              10 Leaves flat in section .... 5. *C. riuminiana*

              10* Leaves lax and drooping in section .... 7. *C. lacrimans*

      6* Apical lamina of megasporophyll > 80 mm long .... 4. *C. aenigma*

    5* Lateral spines on megasporophylls indistinct .... 9. *C. edentata*

this species, native to Japan and China, is widely cultivated throughout The Philippines. It is not discussed any further in this treatment.

A. Section **WADEAE**

Cycas section ***Wadeae*** K.D.Hill & A.Lindstrom, ***sect. nov.***

Inter genus sclerotesta valde longitudinaliter costata distinguenda.

Cycas section *Indosinenses* subsection *Wadeanae* K.D.Hill, abstract in Programme for Cycad 93 Third International Conference on Cycad Biology 15–16 (1993), nom. nud.

Cycas section *Panzhihuanenses* subsection *Wadeanae* (K.D.Hill) D.Y.Wang, Cycads China 27 (1996), nom. inval.

Type: *C. wadei* Merr.

This section is defined by the soft, waxy male cones and microsporophylls, the pectinate megasporophyll apices, the glabrous ovules, and the yellow seeds with a non-fibrous sarcotesta and a strongly longitudinally ribbed sclerotesta. The group is taxonomically somewhat isolated and includes only three Philippine endemic species.

1. *Cycas wadei* Merrill, Philipp. J. Sci. 60(3): 234–236, Pl. 1–4 (1936).

Type: Philippines, Luzon, Culion, *Cogonal Grande, W.H. Brown s.n.* (iso NY, GH, B, G, K, L, MO, P). The holotype at PNH is missing (or was destroyed in WW2).

Cycas circinalis subsp. *riuminiana* var. *curranii* forma *graminea* J. Schust., Pflanzenr. 99: 69 (1932).

Lectotype **(here designated):** Philippines, Luzon, Culion Island, Halsey Harbor near 'Holsey Harbor' (Halsey Harbour), 11 Feb 1902, *E.D. Merrill 657* (lecto NY; isolecto K, L, US). There is no indication by Schuster that he saw any of these sheets and his main material may or may not have been destroyed in Berlin during WW2 hence a lectotype has been chosen.

Literature: Foxworthy (1911, as *C.* sp. aff. *cairnsiana* and *C. sp. (Culion)*), Merrill (1923, as *C. cairnsiana*), Dehgan and Yuen (1983), Zamora and Co (1986), Amoroso (1986).

Illustrations: Merrill (1936), Amoroso (1986).

Etymology: honouring US-born medical doctor working in the Philippines Dr H.W. Wade, the person who brought this species to the attention of its author.

Vernacular: Tagalog—*bayit* (pref. to *bait, vait*), *oliva* (plant, pref. to *oliba, uliba, uliva*), *pitógo* (seed, pref. to *bitogo, patubo, pitugo, potago*) (Amoroso 1986, Bonta & Osborne 2007).

Stems arborescent, to 5 m tall, 10–20 cm diam. at narrowest point; 30–100 leaves in crown. *Leaves* deep green or grey-green, semiglossy 75–180 cm long, slightly to moderately keeled in section (opposing pinnae inserted at 90–150° on rachis), with 160–208 leaflets, tomentum shedding as leaf expands or partly persistent; rachis usually terminated by a spine, 2–30 mm long; petiole 20–40 cm long, glabrous, spinescent for 60–100% of length; basal leaflets not gradually reducing to spines 80–180 mm long. *Median leaflets* simple, strongly discolorous 150–290 mm long, 3–8 mm wide, inserted at 50–60° to rachis, narrowed to 2.5–3 mm at base (to 35–40 % of maximum width), 5–8 mm apart on rachis; section flat or slightly keeled; margins flat; apex aristate, spinescent; midrib raised above, flat below, narrow. *Cataphylls* narrowly triangular, soft, pilose, 70–90 mm long. *Pollen cones* fusiform, green or cream, 40–70 cm long, 7–10 cm diam.; microsporophyll lamina waxy, not dorsiventrally thickened, 21–30 mm long, 15–18 mm wide, fertile zone 25 mm long, sterile apex 6 mm long; apical spine absent or rudimentary, deflexed. *Megasporophylls* 14–22 cm long, brown-tomentose; ovules 2–4, glabrous; lamina orbicular, 70–100 mm long, 55–80 mm wide, deeply pectinate, with 20–30 soft lateral spines 14–35 mm long, 1–2 mm wide; apical spine distinct from lateral spines, 26–45 mm long, 9–14 mm wide at base. *Seeds* subglobose to ovoid, 17–40 mm long, 15–30 mm wide; sarcotesta yellow, not pruinose, 3–4 mm thick, fibrous layer absent; sclerotesta longitudinally ribbed; spongy endotesta absent.

Historical notes: described as a new species in 1936 by American botanist E.D. Merrill. This species was first reported by Foxworthy (1911), who recorded it as sp. aff. *C. cairnsiana* on the basis of observations and collections made by Merrill, who had collected sterile material on an excursion inland from Halsey Harbour on 11 Feb 1902 (*Merrill 657*), and observed that his collection most resembled material of *C. cairnsiana* when at Kew in 1908 (op. cit.). Merrill also later recorded this species as possibly being *C. cairnsiana* (1923), although the same year, he obtained more complete material via Dr Wade that clearly showed that the two were not the same. Wade had transplanted a number of plants to the Culion leper colony, and from them seeds were furnished to the botanic gardens at Kew, New York and Berlin.

Schuster (1932) attached an unwieldy and quite nonsensical quadrinomial to this taxon, using Merrill's original collection (*Merrill 657*) as the type. In placing this within his elaborate hierarchy under *C. circinalis*, he showed just how little he understood of this plant, which in fact belonged in a different section of the genus as he had divided it.

Merrill in the meantime had received more material from Dr A.W. Herre of Culion, which prompted him to look more closely at this taxon. On obtaining more comprehensive collections from W.H. Brown and realising its very distinctive nature, he described it as a new species in 1936, designating the Brown material as 'the type collection'. There has been little subsequent disagreement with this recognition, although Zamora and Co (1986) listed plants from Palawan under *C. wadei* that are quite distinct (see *C. curranii*).

Seeds have been quite widely distributed over the years, and a number of mature plants are present in collections around the world. Fairchild Tropical Garden in Miami has been distributing seeds from their cultivated plants in recent years. Large quantities of seed collections from the wild were distributed in the early 1990's, and plants from these are now abundant in cultivation.

Distinguishing features: readily distinguished by the combination of the symmetrically ribbed sclerotesta and the narrow leaflets. *C. curranii* shares the ribbed sclerotesta, although seeds of the latter are twice as large as those of *C. wadei*. *C. curranii* also has leaflets that are about twice as broad. *C. saxatilis* also has wider leaflets and less keeled leaves.

Distribution and habitat: known only from Culion Island (Fig. 1), on low hills inland from Halsey Harbour on the west of the island. It occurs in a large open area of *Imperata* grassland locally known as the 'cogonal grande' or 'patag grande'. This is a seasonally dry area that suffers frequent grassfires, and the narrow leaflets would appear to be a parallel adaptation to seasonally xeric conditions similar to that seen in Australia (*C. cairnsiana*, *C. calcicola*) and India (*C. beddomei*).

Conservation status: although restricted, the population numbers in excess of 5000 plants, exhibits no signs of decline, and shows active recruitment with all age classes well represented. However, the land is apparently privately owned and not secure in any way. Although at present not threatened, any change in land use could seriously affect the conservation status of this species. Ver 3.1:IUCN (2001) status is **DD** (Donaldson 2003). Recommended status would be **NT.**

Selected specimens: PHILIPPINES: Culion: *Brown s.n.* (GH); Cogonal Grande, *Herre 1061*, 27 Apr 1931 (A); Patag, *Fernando 1611, 1612*, 22 Jun 2001 (LBC).

Mindoro: Oriental prov., Mansalay, fide Zamora & Co (1986); no voucher. **Cult.:** Manilla, *Fenix 121*, 12 Apr 1938 (A); Inst Sci. Manilla, *Quisumbing PNH 4476*, 10 May 1948 (L); Inst Sci. Manilla, *Quisumbing PNH 12163*, 8 Dec 1953 (A); Manilla, *Quisumbing PNH 16845*, Jul 1953 (A).

2. *Cycas curranii* (J.Schust.) K.D.Hill, Proc. Third Int. Conf. Cycad Biol.: 150 (1995).

Cycas circinalis subsp. *riuminiana* var. *curranii* J.Schust., Pflanzenr. 99: 69 (1932).

Type: Philippines, Palawan, Molinao River, on river bank, Mar 1906, *H.M. Curran 3842* (iso K, P). The holotype at PNH is missing (or was destroyed in WW2) and there is no way of knowing whether Schuster had other material at Berlin that also may have been destroyed during WW2.

Literature: Foxworthy (1911, as *C.* sp. Palawan), Merrill (1923, as *C.* sp. Palawan), Zamora & Co (1986, as *C. wadei* in part).

Illustrations: Zamora and Co (1986), Foxworthy (1911 as *C. sp. Palawan*, Plate XXVII)

Etymology: honouring US-born forester Hugo M. Curran, collector of the type specimen.

Stems arborescent, to 1–8 m tall, 14–25 cm diam. at narrowest point; growing in soil or humus; base not strongly swollen; bark thick and corky; 30–120 leaves in crown. *Leaves* deep green or grey-green, highly glossy to semiglossy, 180–260 cm long, slightly keeled or flat (not keeled) in section, opposing leaflets inserted at 150–180° on rachis), with 150–360 leaflets, with white or orange tomentum shedding as leaf expands; rachis usually terminated by paired leaflets; petiole 35–55 cm long (15–30% of total leaf), glabrous, spinescent for 70–100% of length; basal leaflets not gradually reducing to spines, 90–230 mm long. *Median leaflets* simple, strongly discolorous, 210–310 mm long, 10–14 mm wide, inserted at 40–80° to rachis, narrowed to 2.5–3 mm at base (to 15–30% of maximum width), 10–16 mm apart on rachis; section flat; margins flat, not undulate; apex acute, not spinescent; midrib raised above, flat below, narrow. *Cataphylls* narrowly triangular, soft, pilose, 100–130 mm long. *Pollen cones* fusiform, green or cream; microsporophyll lamina soft, not dorsiventrally thickened; raised; apical spine absent or rudimentary, deflexed. *Seed cones* closed at pollination, closed at seed set. *Megasporophylls* c. 21 cm long, grey-tomentose, tomentum shedding; ovules 2–6, glabrous; lamina orbicular, c. 100 mm long, c. 70 mm wide, deeply pectinate, with c. 32 soft lateral spines c. 20 mm long, c. 5 mm wide; apical spine distinct from lateral spines, c. 15 mm long, c. 17 mm wide at base. *Seeds* subglobose to ovoid, c. 48 mm long, c. 40 mm wide; sarcotesta yellow, not pruinose, fibrous layer absent; sclerotesta longitudinally ribbed; spongy endotesta absent.

Historical notes: the first record of a distinctive cycad from Palawan was by American Botanist Merrill, who recorded a distinctive species without a name from Palawan, collected by Curran in 1906 (in Foxworthy 1911, Merrill 1923). German botanist Julius Schuster devised the above quadrinomial based on the same specimen (1932).

This in no way reflects the relationships and affinities of *C. curranii*, and this taxon was generally ignored subsequently until raised to species rank in 1995 by Hill. Zamora and Co (1986) listed plants from Palawan as *C. wadei*, a closely related species. De Laubenfels and Adema (1998) included material of *C. curranii* with quite unrelated material in a confused circumscription of *C. silvestris* (here regarded as an Australian endemic).

Large quantities of large seeds from the wild were distributed in the early 1990's, and plants from these are now abundant in cultivation.

Distinguishing features: readily distinguished by the combination of the symmetrically ribbed sclerotesta and the broad leaflets. Only *C. wadei* shares the ribbed sclerotesta, although seeds are half as large as those of *C. curranii*, and leaflets are narrower.

Distribution and habitat: known only from Palawan Island, apparently an ultramafic endemic, mostly on steep slopes on ultramafics, occasionally on alluvial outwash from ultramafic hills. This species occurs as an understorey plant in rich mixed closed forests, and has been recorded from Puerto Princessa, Aborlan and Narra municipalities (Fig. 1).

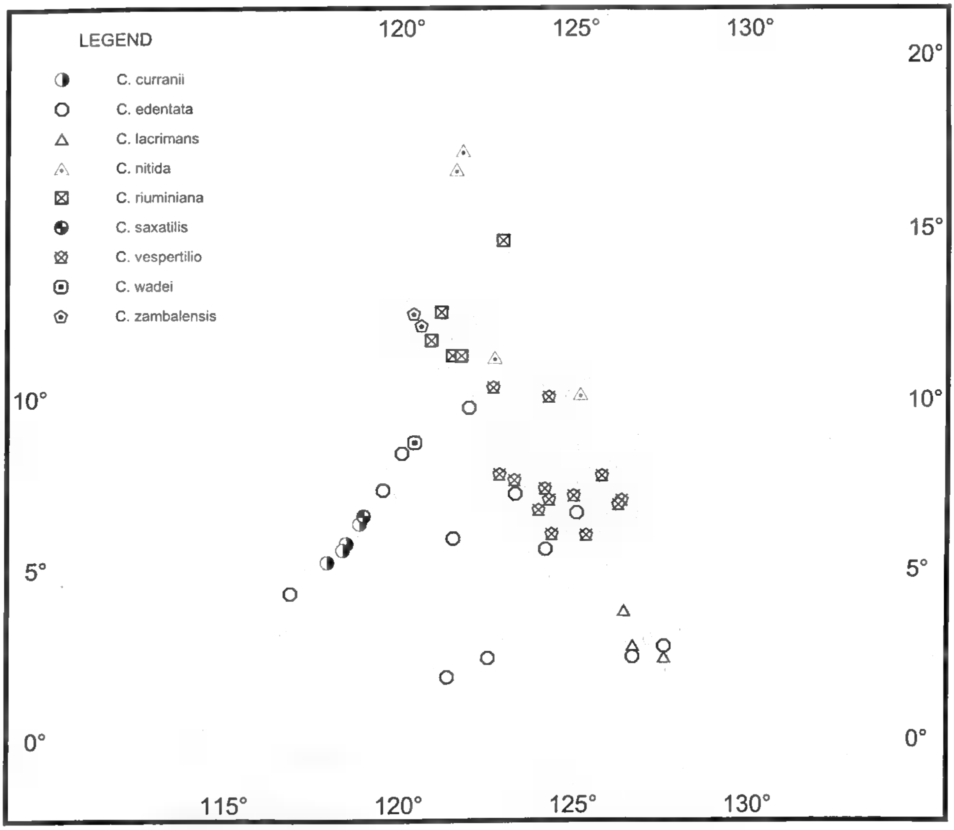

Fig. 1. Distribution of the genus *Cycas* in The Philippines.

Conservation status: widespread over a considerable area, although typically in low population densities. The forest habitat is disturbed in areas at lower elevation and near the coastal plain, but more intact further inland, and large populations probably remain. Ver 3.1:IUCN (2001) status is **DD** (Donaldson 2003). Recommended status would be **NT.**

Selected specimens: PHILIPPINES: Palawan: Narra, Mt Victoria, Trident Mining Co area, alluvial fan at base of ultrabasic mountain, *Podzorski SMHI 2119*, 19 May 1984 (L); Narra, Upper Lapu Lapu (old trident mining area), *Fernando 1613*, 26 Jun 2001 (LBC); Narra, cult. in Antiputuan village, collected from hills to west, *Fernando 1614*, 26 Jun 2001 (LBC); Aborlan, Tabyay River, Baranguy Cabigaan locality, *Fernando 1615*, 26 Jun 2001 (LBC).

3. ***Cycas saxatilis*** K.D.Hill & A.Lindstrom, ***sp. nov.***

Inter species sectionem Wadearum habitatione in rupibus calcareis, strobilis masculis angustioribus praelongisque, microsporophyllis apice non spinosis, megasporophyllis reductis spinis apicalibus elongatis instructis distinguitur.

Type: Philippines, Palawan, St Pauls Bay, major outcrop to SE, pendulous on limestone cliff face, *Podzorski SMHI 2035*, 6 Apr 1984 (holo L).

Etymology: from the Latin *saxatilis*, dwelling among rocks, in reference to the soil-free cliff-face habitat.

Stems arborescent, to 0.5–4 m tall, 20–25 cm diam. at narrowest point,; growing on bare vertical cliffs; base not strongly swollen; bark thin and smooth. *Leaves* bright green, highly glossy, 160–190 cm long, slightly keeled or flat in section (opposing leaflets inserted at c. 150°–180° on rachis), with 170–380 leaflets, tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 40–60 cm long (25–35% of total leaf), glabrous, spinescent for 50–90% of length; basal leaflets not gradually reducing to spines, 150–230 mm long. *Median leaflets* simple, strongly discolorous, 220–340 mm long, 9–12 mm wide, inserted at 50–75° to rachis, decurrent for 3–5 mm, narrowed to 2.5–3 mm at base (to 20–25% of maximum width), 10–17 mm apart on rachis; section flat; margins flat, or slightly recurved, not undulate; apex acute, not spinescent; midrib raised above, raised below, narrow. *Pollen cones* ovoid, cream or green, c. 49 cm long, c. 5 cm diam; microsporophyll lamina soft, not dorsiventrally thickened; level; apical spine rudimentary, upturned. *Megasporophyll* and *seeds* not seen. Fig. 2.

Distinguishing features: it distinguished from all other species in the region by the limestone cliff habitat, the narrow pollen cones with no apical spines on microsporophylls..

The type specimen consist of leaves and a male cone which most closely matches *C. curranii. C. curranii* is tall growing and erect on serpentine soil in rainforest. however the plants that were observed growing at St Pauls Bay are pendulous on limestone cliffs in exposed places and this field observation has lead to the conclusion that they are two different taxa, even though complete material of *C. saxatilis* (i.e. female cones and seeds) have not been seen.

Distribution and habitat: known only from limestone outcrops of the St Pauls Mountain massif on Palawan (Fig. 1). This species grows in crevices in vertical limestone cliffs with no soil.

Conservation status: although it is known from a single locality, this mountain area is quite extensive, and plants are abundant in large, undisturbed populations in the most inaccessable sites. Most of the range is also included in the St Pauls Bay National Park. This species is not regarded as a threatened species. Recommended Ver 3.1:IUCN(2001) status would be **LC.**

Selected specimens: PHILIPPINES: Palawan: Road to St Pauls Bay, *Hill & Lindstrom s.n.*, 25 Jun 2001 (sight record only, no voucher).

B. Section **CYCAS**

Section *Lemuricae* J.Schust., Pflanzenr. 99: 65 (1932), nom. illegit.

Section *Cycas* is defined by the combination of glabrous ovules and a non-pectinate megasporophyll lamina. Three subsections are recognised, circumscription following Hill (1995), with two occurring in The Philippines. The full range of the section is from India and southern Indochina south to Australia, and from East Africa east to Tonga.

Key to the Subsections of Section *Cycas* occurring in The Philippines

1 Seeds with a thick (buoyant) spongy layer inside the sclerotesta .... Subsection *Rumphiae*

1* Seeds with a thin (not buoyant) or absent spongy layer .... Subsection *Cycas*

Fig. 2. *Cycas saxatilis.* Habitat sketch (from K. Hill slide 25.06.2001, *Hill & Lindstrom s.n.*). No scale.

Cycas subsection *Cycas*

This subsection of about 15 species is defined by the absence of a spongy endotesta, and the narrow megasporophyll lamina. It ranges from India and Sri Lanka to Luzon, south and east to New Guinea. Most representatives are plants of closed forests, usually on ridges away from the coast. Five species occur in The Philippines.

4. *Cycas aenigma* K.D.Hill & A.Lindstrom, *sp. nov.*

Inter species philippinenses combinatione characterum sequentium distinguitur: strobili masculi robusti; microsporophylla apice spinis magnis longioribus robustisque; megasporophylla apice elongato attenuatoque et spinis lateralibus elongates instructa.

Type: Philippines, Palawan, cult. Puerto Princessa city, *Fernando 1617,* 26 Jun 2001 (holotype LBC).

Etymology: from the Latin aenigma, to speak darkly, the root of the Engish word enigma, a thing which cannot be satisfactorily explained; a puzzle; a reference to our knowledge of this particularly distinctive species only as a cultivated plant.

Stems arborescent, to 0.5–4 m tall, 20–25 cm diam. at narrowest point; growing in soil; base not strongly swollen; bark thin and smooth. *Leaves* bright green, highly glossy, 200–290 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis), with 300–380 leaflets, tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 40–60 cm long (15–20% of total leaf), glabrous, spinescent for 90–100% of length; basal leaflets not gradually reducing to spines, 220–230 mm long. *Median leaflets* simple, strongly discolorous, 300–340 mm long, 10–13 mm wide, inserted at 60–75° to rachis, decurrent for 3–5 mm, narrowed to 2.5–3 mm at base (to 20–30% of maximum width), 10–12 mm apart on rachis; section flat; margins flat or slightly recurved, not undulate; apex acute, not spinescent; midrib raised above, raised below, narrow. *Cataphylls* narrowly triangular, soft, pilose, 70–100 mm long. *Pollen cones* ovoid, green or cream, c. 34 cm long, c. 16 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, c. 80 mm long, c. 25 mm wide; fertile zone c. 29 mm long, level; apical spine prominent, gradually raised (spreading), c. 47 mm long. *Megasporophylls* 36–40 cm long, brown-tomentose, tomentum shedding; ovules 4–6, glabrous; lamina lanceolate, 220–240 mm long, 35–40 mm wide, deeply pectinate or shallowly pectinate, with 24–34 pungent lateral spines 16–25 mm long, 3–4 mm wide; apical spine distinct from lateral spines, 110–140 mm long, 6–7 mm wide at base. Seeds not observed. Fig. 3.

Historical notes: this singular and distinctive species was not recognised as new until 2001, in cultivation in Puerto Princessa City, and has remained undescribed until now.

Distinguishing features: it is distinguished from all other species in the region by the robust pollen cones with stout, spreading apical spines on microsporophylls and the open seed cones with long megasporophylls and very long attenuate megasporophyll apices with long slender lateral spines. The stout, spreading spines resemble those seen in *C. circinalis* and allies from peninsular India and *C. pranburiensis* from Thailand, but none of these species show the green colour in the male cone or the long-attenuate megasporophyll. It is however, grouped with these species in subsection *Cycas* on the basis of the shared microsporophyll character.

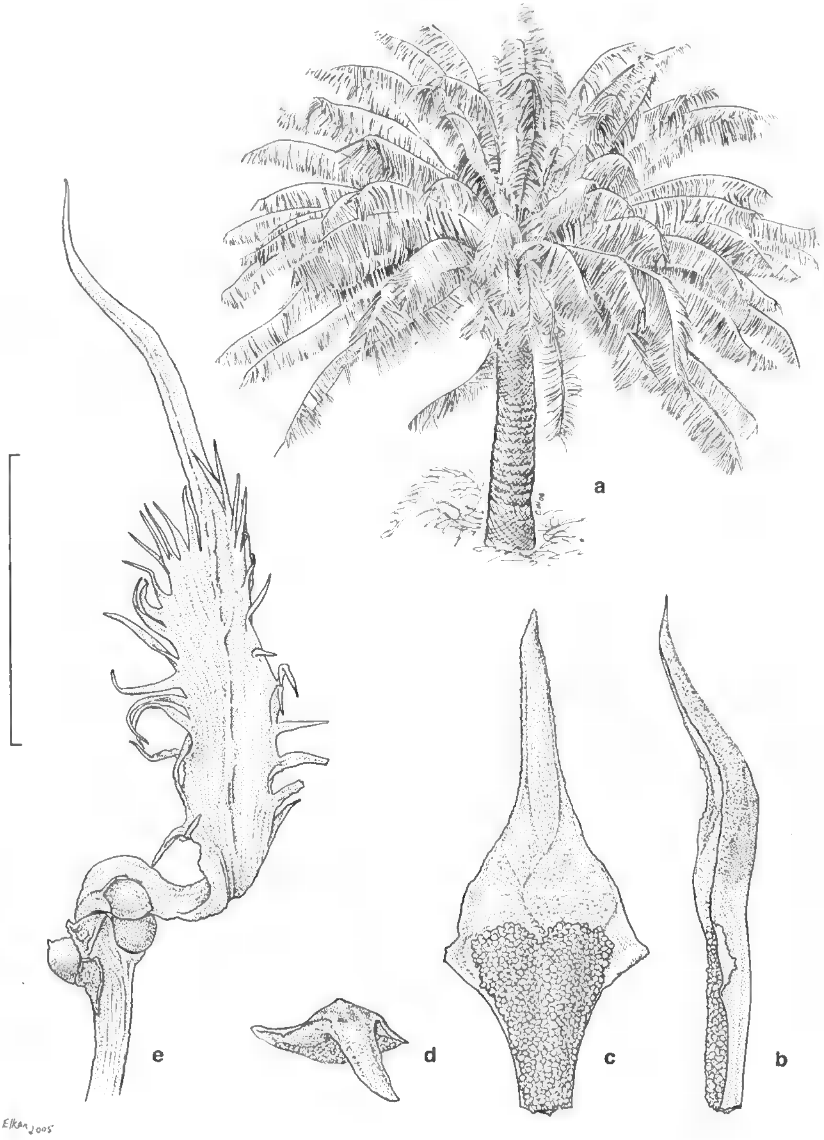

Fig. 3. *Cycas aenigma*. **a,** habit. **b, c, d,** male sporophyll. **e,** female sporophyll (a,b,c,d from K. Hill slides of *Fernando E 1617*, e from K. Hill slide of *Fernando E 1618*). Scale bar: a = no scale; b,c,d = 4 cm; e = 6 cm.

Distribution and habitat: not known. This species is known only in cultivation in Puerto Princessa City on Palawan Island. It is not known if the plants originated on that island, but this seems probable.

Conservation status: Unknown. Recommended Ver 3.1:IUCN(2001) status would be **DD**.

Selected specimens: PHILIPPINES: Palawan: cult. Puerto Princessa city, *Fernando 1618*, 26 Jun 2001 (LBC).

5. *Cycas riuminiana* Porte ex Regel, Gartenflora 12: 16–17 (1863).

Cycas circinalis subsp. *riuminiana* (Porte ex Regel) J. Schust., Pflanzenr. 99: 68 (1932).

Type: ex horto bot. Petropolitano leg. ign. 62.10 (K). De Laubenfels and Adema (1998) designated this specimen as a lectotype, however the status of this specimen as original material is uncertain as there is no date on the sheet nor is it clear that Porte or Regel were the collectors (even though their names appear on the label). No type was cited in the original description. It is likely that Regel described the species from living plants in cultivation at the Imperial Botanic Garden in St Petersburg (see below). Given this uncertainty, it is probably better to consider this sheet as a neotype under the ICBN (Art. 9.8)

Cycas chamberlainii W.H.Brown & Kienholz, Philipp. J. Sci. 26: 47–48, plate 1–2, fig. 1 (1925).

Cycas circinalis subsp. *riuminiana* var. *curranii* forma *chamberlainii* (W.H.Brown & Kienholz) J. Schust., Pflanzenr. 99: 69 (1932).

Type: Philippines, Luzon, Pampanga Prov., Mt. Arayat, 23 May 1923, *Brown & Kienholz Bur. Sci. 42539* (iso NY, A, K, BM, L, P, US). The holotype at PNH is missing (or was destroyed in WW2).

Literature: Lemaire (1864), de Candolle (1868), Miquel (1868), Regel (1876), Foxworthy (1911, in part as *C. circinalis*), Merrill (1923, as *C. rumphii*), Amoroso (1986, in part as *C. circinalis* and also as *C. chamberlainii*), Zamora and Co (1986, as *C. chamberlainii*), de Laubenfels and Adema (1998).

Illustrations: Regel (1863), Lemaire (1864, plate 405) , Foxworthy (1911 as *C. circinalis*, fig 1), Brown and Kienholz (1925, figs 1 & 2), Amoroso (1986, figs 5, 7-9, 27-30 as *C. circinalis* and figs 4, 4–16, 39–41 as *C. chamberlainii*).

Etymology: honouring - Riumin, president of the Moscow Horticultural Society.

Vernacular Ilocano—*sawang* (pref. to *sauang*); Tagalog—*bayit* (pref. to *bait, vait*), *oliva* (plant, pref. to *oliba, uliba, uliva*), *pitógo* (seed, pref. to *bitogo, patubo, pitugo, potago*), *tamok* (Merrill 1923, Zamora & Co 1986, Amoroso 1986, Bonta & Osborne 2007).

Stems arborescent, to 8 m tall, 5–10 cm diam. at narrowest point. *Leaves* bright green, highly glossy or semiglossy, 100–190 cm long, flat (not keeled) in section (opposing pinnae inserted at 180° on rachis), with 120–240 leaflets, tomentum shedding as leaf expands; petiole 25–55 cm long (20–35% of total leaf), glabrous, spinescent for 10–100% of length; basal leaflets not gradually reducing to spines, 150–170 mm long. *Median leaflets* simple, weakly discolorous, 210–310 mm long, 7.5–13 mm wide, inserted at 45° to rachis, decurrent for 6 mm, narrowed to 2–5 mm at base (20–45% of maximum width), 9–18 mm apart on rachis; section flat; margins slightly recurved;

apex aristate, not spinescent; midrib raised above, raised below. *Cataphylls* linear, pungent, pilose. *Pollen cones* ovoid to fusiform, orange or brown, c. 20 cm long, c. 6 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, c. 23 mm long, c. 17 mm wide, fertile zone c. 18 mm long, sterile apex c. 5 mm long, level, apical spine prominent, sharply upturned, c. 11 mm long. *Megasporophylls* 15–24 cm long, brown-tomentose; ovules 4–10, glabrous; lamina lanceolate to elliptical, 43–65 mm long, 15–30 mm wide, shallowly pectinate; with 10–30 pungent lateral spines 2–13 mm long, 1–1.5 mm wide; apical spine distinct from lateral spines, 15–32 mm long, 4–6 mm wide. *Seeds* ovoid, 31–41 mm long, 24–26 mm wide; sarcotesta yellow, 3 mm thick, fibrous layer absent; sclerotesta smooth; thin, spongy endotesta present.

Historical notes: described in 1863 by German-born botanist Eduard Auguste von Regel (1815–1892), Scientific Director and later Director of the Imperial Botanic Garden in St Petersburg, 1855–1892. No type was cited. Plants were imported from Manila by Porte and sold by the Moscow Horticultural Society through the Belgian horticultural trading firm of Verschaffelt. In 1864 Lemaire published a description with a colour plate in L'Illustration Horticole. This species was listed by De Candolle (1868) as "species minus notae" (species without distinction), De Candolle also stated that there was no obvious distinction from *C. circinalis* or *C. rumphii.* Miquel (1868) repeated De Candolle's descriptive notes. Foxworthy in 1911 cited numerous specimens under *C. circinalis*, some of which could possibly represent *C. riuminiana.* This name was ignored by Merrill until listed as a synonym of *C. rumphii* in 1923, although Merrill had noted small-fruited specimens from Mindoro and the Mt Mariveles and Batangas districts of Luzon. The name was ignored by Zamora and Co (1986) and Amoroso (1986); this taxon was treated as *C. circinalis* in both publications.

This species was then described as *C. chamberlainii* in 1925 by William H. Brown, Director of the Philippine Bureau of Science, and Raymond Kienholz, Professor of Botany at the University of the Philippines, who also collected the type specimens. The authors noted that 'it has been known for some time that ... there was a slender mountain form with small seeds which was possibly, or probably, a distinct species', after Merrill (1923). They made no reference to *C. riuminiana*, and may have been unaware of this name.

Schuster (1932) treated *C. riuminiana* as a form of *C. circinalis*, and segregated *C. chamberlainii* as *C. circinalis* subsp. *riuminiana* var. *curranii* forma *chamberlainii.*

Both Amoroso (1986) and Zamora and Co (1986) accepted *C. chamberlainii* as a distinct species, under a restricted circumscription including only the Mt Arayat collections, treating other material here regarded as conspecific as *C. circinalis.*

De Laubenfels and Adema (1998) treated *C. chamberlainii* as a synonym of *C. riuminiana*, and included material now known as *C. falcata* from Sulawesi, Indonesia, in a wide and unclear circumscription.

Distinguishing features: distinguished in the Philippines by the narrow leaflets with a midrib strongly raised above, long sharp cataphylls, and megasporophylls with up to 30 lateral spines 2–13 mm long and a distinct slender apical spine up to 32 mm long.

Distribution and habitat: an inland species of forested areas on ridges and mountains, in closed mixed evergreen forests usually on steep slopes. Abundant on northern Luzon, south at least to Batangas (Fig. 1). Seeds in wide circulation in horticultural circles in the 1990's as "Philippines small seed" apparently belong with this species. These were said to have come from Mindoro, but this has not been confirmed. The mature plants now in cultivation appear to differ slightly from *C. riuminiana* from Luzon (They are more robust with larger seeds), but would seem to fit within an overall range of variation. More field study is obviously required on Mindoro, but this is at present not possible.

Conservation status: although *C. chamberlainii* was reported to have been destroyed in the original habitat by clearing for agriculture and given a 1997 IUCN Red List of Threatened Plants category V, this species actually remains in abundance in healthy populations on Mt Arayat, as well as in many other montane forest areas. Ver 3.1:IUCN (2001) status is **DD** (Donaldson 2003). Recommended status would be **LC.**

Selected specimens: PHILIPPINES: Luzon: Isabela Prov., Mt Dipalayag, Sierra Madre Range, 16°57'N 122°14'E, *Co 3342*, 27 Feb 1991 (A, PNH, L); Pampanga Prov., Arayat, *Loher 4844*, Jun 1896 (K, L); Pampanga Prov., Mt Arayat, *McGregor BS 42080*, Mar 1923 (K, L); Pampanga Prov., Mt Arayat, southern ecotrail, *Fernando 1608*, 19 Jun 2001 (LBC); Bataan Prov., Lamas, *Curran FB 7513*, 19 Apr 1909 (K); Bataan Prov., Lamao River, Mt Mariveles, hill forest, 2000 ft , *Merrill 3257*, Oct 1908 (BM, K, NY, P); Bataan Prov., Mt Mariveles, Lamao River, *Meyer FB 2577* (K, NY); Bataan Prov., Lamao River, *Whitford 1235*, May 1905 (K, NY); Batanes Prov., Batan Island, *Ramos BS 80613*, Jun–Jul 1930 (K, NY); Batangas Prov., Bugaan East, Laurel, cult. in village, coll. on Mt Tagaytay, *Fernando 1604*, 16 Jun 2001 (LBC); Batangas Prov., *Ramos BS 22391*, Jul–Aug 1914 (A, BM, K, L, NSW, NY); Cagayan, fide Amoroso (1986), no voucher; Cavite, fide Amoroso (1986), no voucher; Laguna, fide Amoroso (1986), no voucher. **Cult.:** *Merrill Sp. Blancoanae 855*, Mar 1915 (A, BM, BO, K, L, NSW, NY); cult. Kew, 19 Jan 1897 (K); Manilla & vicinity, *Merrill 9795*, Dec 1914 (A, BM, BO, L, NY, P); ex horto Bot. Petropolitano, *leg. ign. 70.7* (LE).

6. *Cycas vespertilio* A.J.Lindstrom & K.D.Hill, *sp. nov.*

Inter species philippinenses combinatione characterum sequentium distinguitur: foliola lata, megasporophylla elongata ad apicem alata.

Type: Philippines: Panay: Iloilo, Barotac Viejo, Barangay Lipata, Sitio Nagpana, Mt. Opao, *Lindstrom AL 06/008*, 4 Mar 2006 (holotype LBC; iso NSW, BKF).

Etymology: the specific epithet is from the Latin *vespertilio*, a bat, from *vesper* (evening), literally 'the little one of the evening', in reference to the wing-like extensions on the megasporophyll apex.

Stems arborescent, to 1–3 m tall, 12–20 cm diam. at narrowest point; base not strongly swollen; bark thin with persistent cataphylls. *Leaves* bright green, glossy, 128–210 cm long, flat (not keeled) in section, with 93–117 leaflets tomentum shedding as leaf expands; petiole 46–52 cm long, shedding brown tomentum, spinescent for 90–100% of length; basal leaflets not gradually reducing to spines, 180–200 mm long. *Median leaflets* simple, not discolorous, keeled in transect, 270–290 mm long, 10–13 mm wide, narrowed to 2–3 mm at base, 10–14 mm apart on rachis; section flat; margins edged, or slightly recurved, undulate; apex acute, not spinescent; midrib raised above, raised below, narrow. *Cataphylls* broadly triangular, stiff, pilose, 55–60 mm long. *Pollen cones* not seen. *Megasporophylls* 17–19 cm long, cream-tomentose, tomentum not shedding; ovules 6–7, glabrous; lamina rhomboid, winged, 160–180 mm long, 32–35 mm wide, lateral spines 2, broad, flattened & wing-like; apical spine distinct from lateral spines, 35–38 mm long, 3–5 mm wide at base. *Seeds* obovoid, c.36 mm long, 27 mm wide; fibrous layer absent; sclerotesta smooth; spongy endotesta present, thin (see discussion under *C. zambalensis*). Fig. 4.

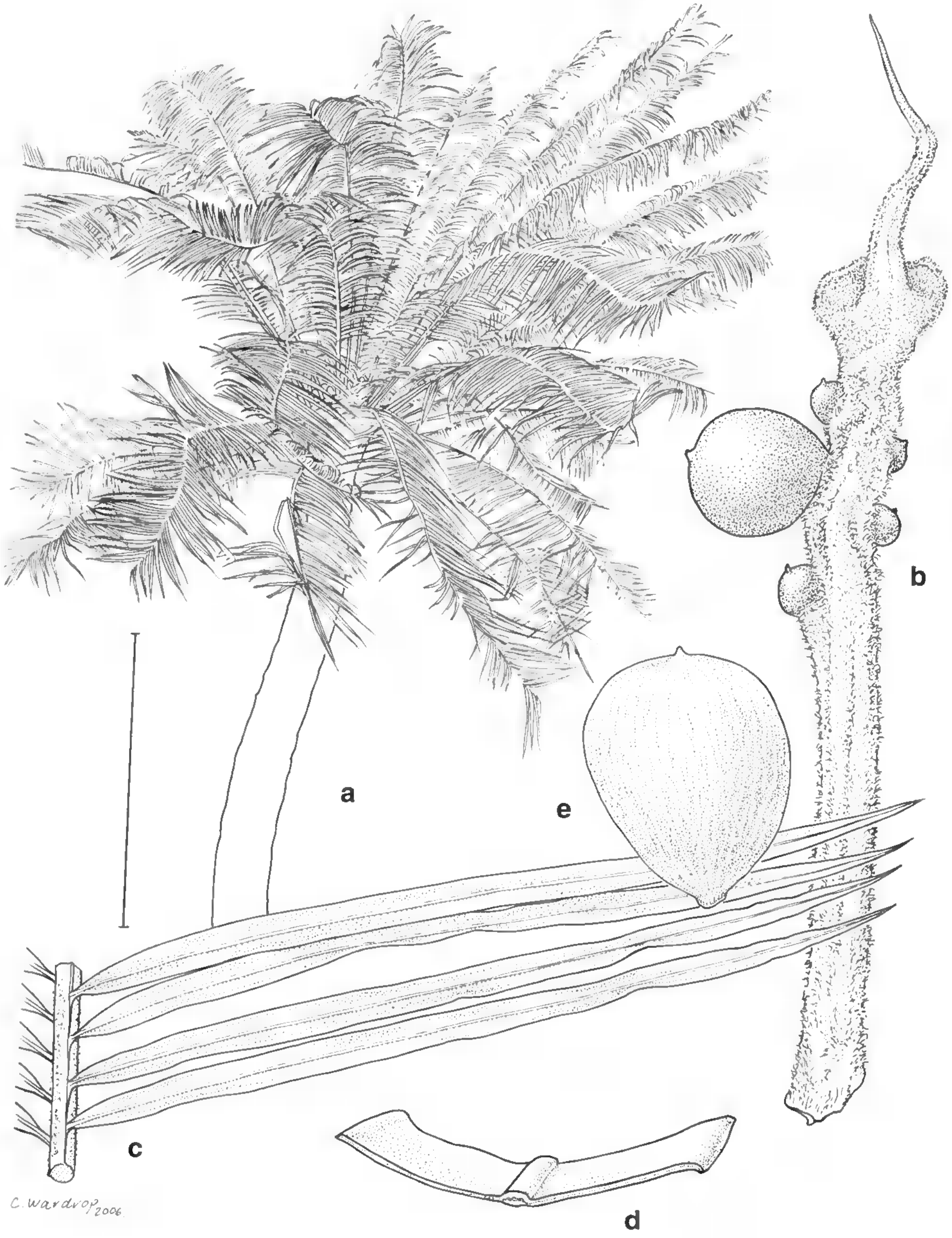

Fig. 4. *Cycas vespertilio.* **a,** sketch of habit (from A. Lindstrom slide). **b,** female sporophyll. **c,** part of leaf. **d,** cross-section of leaflet. (b,c,d,from *Lindstrom AL 06/008*), **e,** seed (from *NSW 638085*). Scale bar: a = no scale, b = 4 cm, c = 10 cm, d = 1 cm, e = 4 cm.

Historical notes: although first collected in 1928 by Edaño, this taxon was not recognised as a distinct species until 2006.

Distinguishing features: the megasporophylls with two lateral wings distinguish this from all other Philippine cycads. The seeds are obovoid and somewhat dorsiventrally flattened.

Distribution and habitat: Philippines, hill forests of Panay, Negros, Cebu, Leyte, Samar and southernmost Luzon (Fig. 1). Seasonally deciduous forest with *Pterocarpus indicus* and bamboo. Yellow clay overlying sandstone or volcanic cinders. Southwest facing slopes sometimes in full sun but more often in shaded situations.

Conservation status: taking the wide distribution range in account the species is not under immediate threat. However, deforestation on Negros, Panay and Leyte is already extreme and little habitat is left. Recommended Ver 3.1:IUCN(2001) status would be **NT.**

Selected specimens: PHILIPPINES: Leyte: Gigantangan (? Hingatungan), *Kondo & Edaño PNH 36862*, 30 Mar 1957 (L). **Luzon:** Panagan River, Camarines Sur, *Edaño BS 76373*, Dec 1928 (BO, G, NY). **Marinduque:** Torrijos, Bonliw, Talisay, *Fernando* 606, 7 Aug 1996 (LBC 7181, K?). **Mindoro:** Mt Yagaw, E slope, *Conklin PNH 18682*, 27 Jul 1953 (A, L); Mt Yagaw, E slope, edge of mangrove swamp, *Conklin PNH 37914*, 12 Apr 1958 (A, L). **Negros:** Negros Oriental, cult. in house, not of confirmed origin but said to have been collected from the extreme south of the island, *Lindstrom AL06/006*, 3 Mar 2006 (NSW). **Panay:** Nagpana, Barotac Viejo, Iloilo, 11°02'N 122°15'E, *Madulid 7232*, 15 Nov 1989 (A). **Cult.:** Pasay City, *Mendoza PNH 37074*, 2 Jul 1956 (BM, L).

7. *Cycas lacrimans* A.J.Lindstrom & K.D.Hill, *sp. nov.*

Inter species philippinenses combinatione characterum sequentium distinguitur: foliola demissa; megasporophylla elongata spinis lateralibus reductis; fructus non spongiosus.

Type: Philippines: Mindanao: Davao, Mati, *Ramos & Edaño BS 48953*, Mar–Apr 1927 (holo NY, iso BM, BO, P).

Etymology: the specific epithet is from the Latin *lacrimans*, crying, in reference to the drooping or weeping habit of the leaves.

Stems arborescent, to 1–2 m tall, 18–20 cm diam. at narrowest point; base not strongly swollen; bark thin with persistent cataphylls. *Leaves* glossy green, 168–200 cm long, flat (not keeled) in section, with 76–85 leaflets; petiole 45–50 cm long, lacking tomentum, spinescent for 90–100% of length with needle-like stout 6 mm long spines; basal leaflets not gradually reducing to spines, 170–190 mm long. *Median leaflets* simple, discolorous underneath, 280–320 mm long, 7–13 mm wide, narrowed to 2–3 mm at base, 12–14 mm apart on rachis; section recurved; margins folded, not undulate; apex acute, not spinescent; midrib sunken above, raised below. *Cataphylls* broadly triangular, stiff, pilose, 55–60 mm long. *Pollen cones* ovoid, light brown, c. 42 cm long, c.16 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, c. 34 mm long, 19 mm wide, fertile zone 34–38 mm long, sterile apex 1–2 mm long, level; apical spine very slender, 12–17 mm long. *Megasporophylls* c. 37 cm long, cream-tomentose, tomentum not shedding; ovules 4–6, glabrous; lamina triangular, c. 55 mm long, c. 20 mm wide, lateral spines shallowly pectinate; with 15–24 pungent lateral spines 3–8 mm long, 1–2 mm wide; apical spine distinct from lateral spines, 35–38 mm long, 3–5 mm wide at base. *Seeds* oblong, c. 40 mm long, c. 20 mm wide; sclerotesta smooth; spongy endotesta absent. Fig. 5.

Fig. 5. *Cycas lacrimans.* **a,** sketch of habit (from A. Lindstrom slide). **b,** part of leaf. **c,** cross-section of leaflet (from *Lindstrom AL 06/004*). **d,** male sporophyll (from NY digital image of NY sheet of *Ramos & Edano 48953*). **e,** female sporophyll (reconstructed from *Lindstrom AL 07/018*). Scale bar: a = no scale, b = 10 cm, c = 0.6 cm, d = 6 cm, e = 3 cm.

Historical notes: although first collected in 1927 by Ramos & Edaño, this taxon was not recognised as a distinct species until 2006.

Distinguishing features: the long megasporophylls with reduced lateral spines, the seeds with no spongy endotesta and the lax, drooping leaflets distinguish this from all other Philippine species.

Distribution and habitat: Philippines, known at present only from hill forests of eastern Mindanao (Fig. 1). Serpentine soil.

Conservation status: if restricted to this small area the species is in need of urgent protection in situ. Deforestation and other habitat destruction is extreme. Recommended Ver 3.1:IUCN(2001) status would be **EN.**

Selected specimens: PHILIPPINES: Mindanao: Davao Oriental, Municipality of San Isidro, cult. in house at the foothill of Mt. Galintan, planted 1960's, said to come from nearby now destroyed seaside, *Lindstrom AL 06/004*, 29 Feb 2006 (NSW); Davao Oriental, Barangay Sto. Rosario, Mati district, Mt.Hamiguitan, Maeudlong Forest Reserve, *Lindstrom AL 07/018*, 12 Mar 2007 (NSW); Davao, Mt Galintan, *Ramos & Edaño BS 48912*, Jun 1927 (NY); Bukidnon, fide Amoroso (1986) as *C. circinalis*, no voucher; Surigao, fide Amoroso (1986) as *C. circinalis*, no voucher; Zamboanga, fide Amoroso (1986) as *C. circinalis*, no voucher.

8. *Cycas zambalensis* Madulid & Agoo, Blumea 50(3): 519–522 (2005).

Type: Philippines, Zambales, San Antonio, *Madulid & Agoo PNH 173358*, 2005 (holo PNH).

Illustrations: Madulid & Agoo (2005).

Etymology: the specific epithet refers to the name of the locality, Zambales, where this population is located.

Stems arborescent, to 3 m tall, 15 cm diam. at narrowest point; base not strongly swollen. *Leaves* dark green, semiglossy, 100–190 cm long, keeled in section (opposing leaflets inserted at less than 180° on rachis), with 99–260 leaflets, with brownish tomentum not shedding as leaf expands; petiole 30–44 cm long (25–33% of total leaf), tomentose, spinescent for 60–80% of length; basal leaflets not gradually reducing to spines, 130 mm long. *Median leaflets* simple, 120–260 mm long, 5–8 mm wide, 5–10 mm apart on rachis; narrowed to 2.5 mm at base, margin straight; midrib flat above, raised below. *Cataphylls* narrowly triangular, needle-like, 60–70 mm long, stiff, pilose. Pollen cones brownish orange, ovoid to long ovoid, tapering, to 36 cm long, to 18 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, 30–50 mm long, 10–30 mm wide; apical spine prominent, sharply upturned or gradually raised, 5–25 mm long. *Megasporophylls* 22–35 cm long, densely brown-tomentose, tomentum persistent; ovules 4–6, glabrous; lamina ovate or lanceolate, 70–80 mm long, 40–50 mm wide, shallowly pectinate, with 20–34 pungent lateral spines 6–14 mm long, c. 1 mm wide; apical spine distinct from lateral spines, 30–35 mm long, 5–7 mm wide. *Seeds* flattened-ovoid, to 43 mm long, to 36 mm wide; sarcotesta yellow, not pruinose; fibrous layer absent; sclerotesta smooth; spongy endotesta present, thin.

Historical notes: this endemic species was discovered and described in 2005.

Distinguishing features: the species is easily distinguished from the other Philippine *Cycas* in having tomentose pinnae and rachis. The pinnae of *C. zambalensis* are also rigid and stiff, and the leaves are keeled. Based on these characteristics, the young individuals of *C. zambalensis* resemble *C. revoluta*, a common ornamental plant in the country.

Cycas zambalensis is very similar to *C. riuminiana* (syn: *C. chamberlainii*), also found in the Philippines, in having long petioles (at least 25 cm) and very woolly megasporophylls. The species differs from *C. riuminiana* in having narrower pinnae, longer than wide sterile apex of the megasporophyll, larger apical spine on the megasporophyll, persistently lanate megasporophylls, and tomentose leaflets and rachis. The hairs persist even in dried specimens. The pinnae are short, rigid and stiff, and the leaves are keeled. The seeds are slightly flattened.

A spongy endotesta was observed in one cultivated individual (*Fernando 1605*). This might represent present or past hybridization with subsection *Rumphiae* either in the ancestry of this group or this plant.

Distribution and habitat: San Antonio, Kawag, Bucao, Zambales, NW Luzon. Endemic (Fig. 1).

Cycas zambalensis is restricted to the ultrabasic grassy hills of Zambales, a distinct biogeographic region in the western part of Luzon Island. The plants are usually scattered wide apart on the hillsides and do not form distinct groups. Plants grow fully exposed to the sun and strong wind near the sea.

The population dominates the seasonally dry, hilly grasslands of the Zambales Peninsula, which is distinct from the lowland evergreen rain forests of the Bataan-Zambales mountain range. The soils in the area are ultramafic and rich in chromite deposits. There are two pronounced seasons in the province: the dry season which is from November to April and the wet season for the rest of the year. Maximum rainfall occurs from June to September which coincides with the southwest monsoon.

Conservation Status: the very limited distribution of *C. zambalensis*, changing land use of the habitat of the species, and increasing pressure from collection for the horticultural trade are serious threats to the species. It is considered a critically endangered species. The effect of occasional fire to the population has yet to be evaluated. Recommended Ver 3.1:IUCN(2001) status would be **CR** (Madulid & Agooo 2005).

Selected specimens: PHILIPPINES: Luzon: Bataan Prov., Subic Bay Freeport zone, cult. in Summit Hotel complex, coll. just outside freeport zone, *Fernando E 1605, 1606,* 18 Jun 2001 (LBC); Zambales, San Antonio district, Barangay Punakit, on the slopes of Mt.Anawangan, GPS: N 14°55.293'E 120°04.239' Alt. 300 m, *Lindstrom AL 06/013, AL 06/014*, 8 Mar 2006 (NSW); cultivated in the town of San Antonio, along the way to the beach, *Lindstrom AL 06/015*, 8 Mar 2006 (NSW); Bataan, Subic bay district, cultivated outside the restaurant at Crown Peak Hotel within former US Navy base, *Lindstrom AL 06/016, AL 06/017*, 8 Mar 2006 (NSW).

Cycas* subsection *Rumphiae K.D.Hill, Austral. Syst. Bot. 7: 548 (1994).

Type: *C. rumphii* Miq., Bull. Sci. Phys. Nat. Neerl. 2: 45 (1839).

This subsection is uniquely defined by the presence of a layer of spongy tissue within the seed. Microsporophylls are also distinctive, being more or less dorsiventrally thickened, with short or vestigial, sharply upturned apical spines. Another potentially synapomorphic character defining this group is the 2-year seed maturation period, although this has been confirmed only for *C. seemannii*, *C. thouarsii* and *C. bougainvilleana*. All other species of *Cycas* for which data is available have a seed maturation period of less than one year.

Distribution is very wide, extending from Africa to Fiji and Tonga, and from New Guinea north to southern coastal Indochina. Two species occur in The Philippines.

The spongy endotesta causes seeds to be buoyant, and has been proposed as a dispersal mechanism (Dehgan & Yuen 1983). This dispersal mechanism has been interpreted as a cause of the taxonomic complexity of this group, with successive colonisation events producing the high local variability in some populations and the very different forms sometimes occurring in close proximity (Hill 1994, Fosberg & Sachet 1975).

9. ***Cycas edentata*** de Laub., in De Laub. & Adema, Blumea 43: 372 (1998).

Type: Philippines, Sulu Archipelago, Mt Cabucan, *Kondo & Edaño 38877*, Jan–Feb 1957 (holo L; iso A, BM).

Cycas litoralis K.D.Hill, Brittonia 51(1): 70, fig. 11 (1999).

Type: Thailand. Ao Manao Naol, Narathiwat, *K.D. Hill 4627 & Poonsak Vatcharakorn*, 20 Apr 1994 (holo NSW; iso BKF, K, L, PE)

Cycas circinalis subsp. *riuminiana* var. *curranii* forma *maritima* J. Schust., Pflanzenr. 99: 69 (1932).

Lectotype (**here designated**): Philippines, Calusa Island, 29 July 1912, *Fenix 15660* (lecto K, isolecto L). Schuster cited a number of specimens in his protologue. The specimen chosen as lectotype is one that is stated as being a coastal collection.

Literature: Kurz (1877, as *C. rumphii*), Foxworthy (1911, as *C. circinalis*), Merrill (1912, as *C. circinalis*), Merrill (1917, as *C. rumphii*), Merrill (1918. as *C. circinalis*), Merrill (1921, as *C. circinalis*), Merrill (1923, as *C. rumphii*), Backer (1925, as *C. rumphii* p.p.), Ridley (1925, as *C. rumphii*), Leandri (1931, as *C. rumphii*), Ochse (1931, as *C. rumphii* p.p.), Schuster (1932, as *C. rumphii* p.p.), Kanehira (1938, as *C. rumphii* p.p.), Ho and Duong (1960, as *C. rumphii*), Suvatabandhu (1961, as *C. rumphii*), Backer and Bakhuizen van den Brink (1963 as *C. rumphii* p.p.), Smitinand (1971 as *C. rumphii*), Smitinand (1972 as *C. rumphii*), Zamora and Co (1979 as *C. circinalis* in part), Amoroso (1986 as *C. rumphii*), Hill and Yang (1999 as *C. litoralis*).

Illustrations: Ridley (1925), Schuster (1932 as *C. rumphii* p.p.), Smitinand (1971), Cheng et al. (1975, as *C. rumphii*), Amoroso (1986, as *C. rumphii*), de Laubenfels & Adema (1998), Hill and Yang (1999, as *C. litoralis*)

Etymology: from the Latin *dentata*, toothed, with the Latin prefix *e-*, without, in reference to the megasporophyll apices.

Vernacular: Malay - *kwale pahang* (woods on sea shore), Thai - *prong thale* (sea cycad), Ilocano - *sauang, sawang*, Tagalog - *bait, bayit, pitógo* (preferred to *potago, patubo, pitugo* or *bitogo*), Spanish - *oliba, oliva* (preferred), *uliba, uliva*, unidentified lang. - *vait* (Hill & Vatcharakorn 1998, Ridley 1893, Amoroso 1986, Schuster 1932, Zamora & Co 1986, Bonta & Osborne 2007).

Stems arborescent, to 10 m tall, to 20 cm diam. at narrowest point, numerous leaves in crown. *Leaves* bright to deep green, highly glossy, 130–230 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis), with 100–200 leaflets, tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 30–90 cm long (20–50% of total leaf), glabrous, spinescent for 5–100% of length; basal leaflets not gradually reducing to spines, 120–280 mm long. *Median leaflets* simple, strongly discolorous, 220–370 mm long, 11–19 mm wide, inserted at 45–80° to rachis, decurrent for 5–13 mm, narrowed to 5–8 mm at base (to 35–50% of maximum width), 12–35 mm apart on rachis; section flat; margins slightly recurved, not undulate; apex acute, not spinescent; midrib flat or raised above, raised below, wide. *Cataphylls* narrowly triangular, soft, pilose, 40–70 mm long. *Pollen cones* narrowly ovoid or fusiform, orange, 35–60 cm long, 11–17 cm diam; microsporophyll lamina firm, not dorsiventrally thickened, 35–44 mm long, 12–23 mm wide, fertile zone 30–35 mm long, sterile apex 5–6 mm long, level to slightly deflexed; apical spine prominent, sharply upturned, 9–24 mm long. *Seed cones* open at pollination, open at seed set. *Megasporophylls* 24–50 cm long, white-, yellow-tomentose or brown-tomentose, tomentum persistent; ovules 2–8, glabrous; lamina lanceolate, 43–120 mm long, 20–40 mm wide, lateral spines short or indistinct; apical spine distinct from lateral spines, 14–40 mm long, 4–12 mm wide at base. *Seeds* flattened-ovoid, 45–66 mm long, 35–50 mm wide; sarcotesta orange-brown, not pruinose, 3–5 mm thick; fibrous layer absent; sclerotesta smooth; spongy endotesta present.

Historical notes: known since the earliest accounts of the Philippine flora, this species was only described by de Laubenfels and Adema in 1998. This taxon has been included in *C. rumphii* by numerous authors, starting with Kurz in (1877), with the exception of Foxworthy (1911) and Merrill (1912, 1918, 1921) as *C. circinalis*. Schuster (1932) described it as *C. circinalis* subsp. *riuminiana* var. *curranii* forma *maritima*. Hill recognised this as a distict taxon in 1995 (Hill 1998) and formally described the taxon as *C. litoralis* in April 1999. De Laubenfels had already described this taxon as *C. edentata*, published in 1998 but with a confused circumscription that included *C. glauca, C. rumphii* and others.

Distinguishing features: very highly glossy leaves; long spines on microsporophyll tips, no or rudimentary teeth on megasporophyll tips, spongy endotesta in seed.

Distribution and habitat: usually in littoral forests or on beachfronts, widespread and locally common in much of south-east Asia (Fig. 1).

Conservation status: this species occurs in coastal sites that have experienced severe pressures from population increase and development. This habitat is also coming under increasing pressure for aquaculture sites. Although probably not immediately threatened, it is potentially vulnerable in the longer term. Ver 3.1:IUCN(2001) status is **DD** (Donaldson 2003) for The Philippines. Recommended status would be **NT.**

Selected specimens: PHILIPPINES: Balabac: Bancalan Is, *Weber s.n., 7.1916* (A). **Basilan:** *Klemme FB 15219*, Aug 1910 (K, L); Basilan, *Hutchinson FB 3441*, 10 Dec 1905 (K). **Cagayan Is:** Calusa Is., *Fenix BS 15660*, 29 Jul 1912 (BM, K, L). **Cebu:** Lapu Lapu City, Olango Island, *Madulid et al. PPI 7622*, 20 Mar 1993 (BO). **Masbate:** Hamoraon Island, *Kondo & Edano PNH 36862*, 30 Mar 1957 (L). **Mindanao:** Prov. Davao, Santa Cruz, *Williams 2890*, 17 Jun 1905 (NY); Prov. Davao, between Digas and Santa Cruz, *Williams 3058*, 29 Jun 1905 (GRAY, K, NY); Davao Oriental, Mati district, Mayo Bay, cult. at the House of F.G.R.Dahican (Mayor), Planted 1960's, said to come from nearby now destroyed seaside, *Lindstrom AL 06/001, AL 06/002*, 29 Feb 2006 (NSW); Caldera, *Wilkes exped. s.n.*, 1832–1842 (GRAY); Zamboanga Prov., *Merrill 11638*, Sep 1922 (A, BO). **Mindoro:** Bongabon and Pinamalayan, *Maliwang 253*, 5 Feb–5 Apr 1941 (A). **Negros:** Negros Oriental, Dumaguete district, Secondary seriously destroyed seaside forest, *Lindstrom AL 06/005*, 3 Mar 2006 (NSW). **Panay:** Iloilo, fide Amoroso (1986), no voucher. **Palawan:** Culion, Alava Island, Halsey Harbour, *Fernando 1609, 1610*, 22 Jun 2001 (LBC); cult. Puerto Princessa city, coll. from coastal forest near San Vicente, *Fernando 1616*, 26 Jun 2001 (LBC).

10. *Cycas nitida* K.D.Hill & A.Lindstrom, *sp. nov.*

Inter species philippinensis combinatione characterum sequentium distinguitur: folia nitida; strobili masculi parvi; microsporophylla apice spinis magnis longioribus robustisque; megasporophylla elongata spinis lateralibus prominentibus; fructus non spongiosus.

Type: Philippines, Luzon, seeds from Rapu Rapu Is., E. of Luzon, plant (female) cult. Sydney Botanic Gardens, 2006 (holo NSW 728768).

Etymology: from the Latin *nitida*, shining, in reference to the extremely glossy leaves.

Stems arborescent. *Leaves* deep green, highly glossy, 150–180 cm long, flat (not keeled) in section (opposing pinnae inserted at 180° on rachis), with 160–200 leaflets tomentum shedding as leaf expands; petiole 30–60 cm long, glabrous, spinescent for 50% of length; basal leaflets not gradually reducing to spines, 270 mm long. *Median leaflets* simple, strongly discolorous, 270–370 mm long, 14–18 mm wide, 12–17 mm apart on rachis; section flat; margins slightly recurved; apex acute, not spinescent; midrib raised above, raised below. *Cataphylls* narrowly triangular, soft, pilose. *Pollen cones* fusiform, orange, 16 cm long, 4.5 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, 37–44 mm long, 12–23 mm wide; apical spine prominent, sharply upturned, 13–23 mm long. *Megasporophylls* 24–34 cm long, brown-tomentose; ovules 2–4, glabrous; lamina lanceolate, 43–60 mm long, 20–30 mm wide, distinctly dentate; with 8–16 lateral spines, pungent, 3–5 mm long; apical spine distinct from lateral spines, 14–20 mm long. *Seeds* flattened-ovoid, 55–66 mm long, 45–50 mm wide; sarcotesta orange-brown; fibrous layer absent; sclerotesta smooth; spongy endotesta present. Fig. 6.

Distinguishing features: very highly glossy leaves; small male cones, long spines on microsporophyll tips, distinct teeth on megasporophyll tips, spongy endotesta in seed.

Distribution and habitat: Philippines only, usually in littoral forests on the north and east of Luzon island (Fig. 1).

Conservation status: this species occurs in coastal sites that have experienced severe pressures from population increase and development. This habitat is also coming under increasing pressure for aquaculture sites. Although probably not immediately threatened, it is potentially vulnerable in the longer term. Recommended Ver 3.1:IUCN(2001) status would be **NT.**

Selected specimens: PHILIPPINES: Luzon: Alabat Island, *Ramos & Edaño BS 48310*, Sep–Oct 1926 (LE, NY); Tabayas Prov., *Curran 10319*, 4.1908 (NY); Prov. Dalupir Is, Babuyan group, 19°10'N 121°15'E, *Bartlett 15158*, 31 Oct–5 Nov 1935 (A). **Polillo:** fide Amoroso (1986), no voucher. **Cult.:** male and female plants, S.J. Walkley, Burpengary, seeds from Rapu Rapu Is., E. of Luzon, *Walkley s.n.* (NSW 728765, 728767, 731813); male plant, Sydney Botanic Gardens (NSW 930437, 619428)

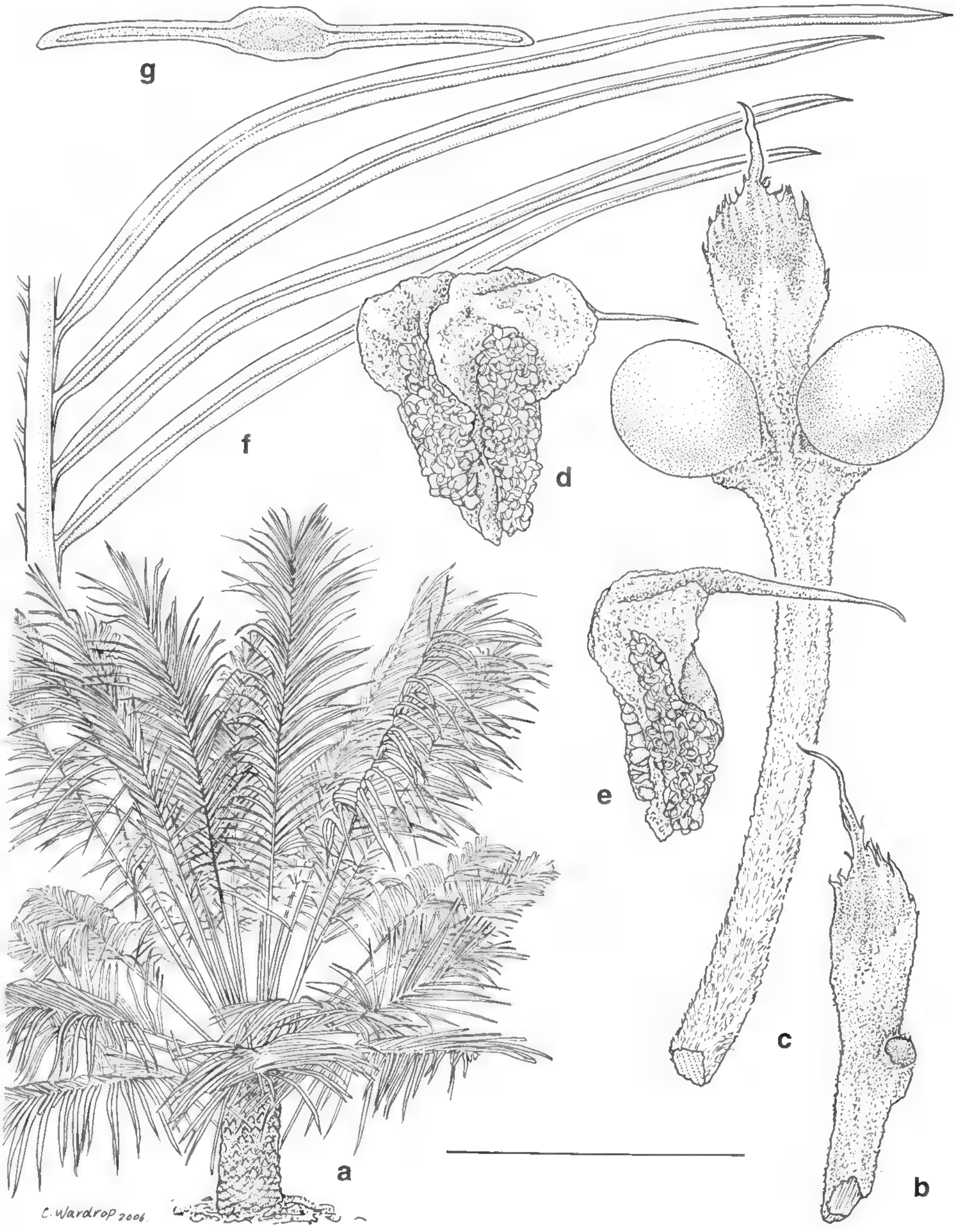

Fig. 6. *Cycas nitida*. **a,** sketch of habit (from digital image of S.J. Walkley cult. plant). **b,** immature female sporophyll (from *NSW 728765*). **c,** mature sporophyll (from *NSW 731813*). **d, e,** male sporophyll (d, e, from *NSW 728767*). **f,** part of leaf. **g,** cross-section of leaflet (f, g, from *NSW 728765*). Scale bar: a = no scale, b,c = 6 cm, d,e = 2 cm, f = 10 cm, g = 1 cm.

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A review of *Drosera whittakeri* s. lat. (Droseraceae) and description of a new species from Kangaroo Island, South Australia

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Abstract

A review of *Drosera whittakeri* s. lat. is presented, along with its more distant relative *D. praefolia*, and the case for recognition of the latter. *Drosera whittakeri* subsp. *aberrans* Lowrie & Carlquist is raised to specific status as ***D. aberrans*** (Lowrie & Carlquist) Lowrie & Conran. As none of the original collections appear to have survived, a neotype is selected for *D. whittakeri* from close to Whittaker's original collection locality. A new Kangaroo Island endemic species, ***D. schmutzii*** Lowrie & Conran, is described and illustrated. SEM micrographs of the seeds and a key to the four taxa are also provided.

Introduction

Drosera whittakeri Planch., as presently understood, is the only eastern Australian member of *Drosera* subgen. *Ergaleium* sect. *Erythrorhiza* (Lowrie 1987). This section is characterised by having tubers, a vertical, subterranean primary stem with prophylls; leaves rosulate, exstipulate, non-peltate, sessile or broadly petiolate; flowers sweetly scented; and styles 3 with many, divided, filiform segments (Marchant et al. 1982). In addition, replacement tubers show the unusual habit of developing inside the degenerating tissues of the parent tuber (Conran 2008).

There are different interpretations of the taxonomy of *D. whittakeri*, ranging from a single, very variable species (e.g. Marchant et al. 1982, Marchant 1986, Schlauer 2006); two subspecies recognised within *D. whittakeri* (Lowrie & Carlquist 1992, Schlauer 1996, Clayton 2003); and/or the recognition of *D. praefolia* Tepper as separate from *D. whittakeri* (Bates 1991, Gibson 1995, Lowrie 1998, Clayton 2003, CHAH 2006).

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Drosera praefolia was distinguished from *D. whittakeri* s. lat. by its white tuber, flowers borne on lateral inflorescences that emerge before the leaves; and variably obovate, elliptic and orbicular leaves all within the same rosette (Bates 1991). Similarly, *D. whittakeri* subsp. *aberrans* Lowrie & Carlquist was separated from subsp. *whittakeri* based on its few-flowered, stoloniferous, colony-forming habit.

In September 2002, Erwin Schmutz discovered an apparently new taxon on Kangaroo Island (here described as *D. schmutzii*), recognising that it differed from material currently included in *D. whittakeri*. This taxon was also collected independently by Clayton (2003), who provided informal descriptions, photographs and information about its distribution and habitat. Field observations and comparison of the plant with *D. whittakeri* and *D. praefolia* suggested that not only was this new taxon distinct, but that the other taxa associated with *D. whittakeri* were all sufficiently different to justify specific rank (Table 1).

Although three members of the complex occur on Kangaroo Island (Fig. 1), the new taxon is the only endemic. It co-occurs occasionally with *D. praefolia* and only extremely rarely with *D. whittakeri* s. str. (Clayton 2003), but differs from both in numerous features (Table 1), and cannot be confused easily with other members of the complex.

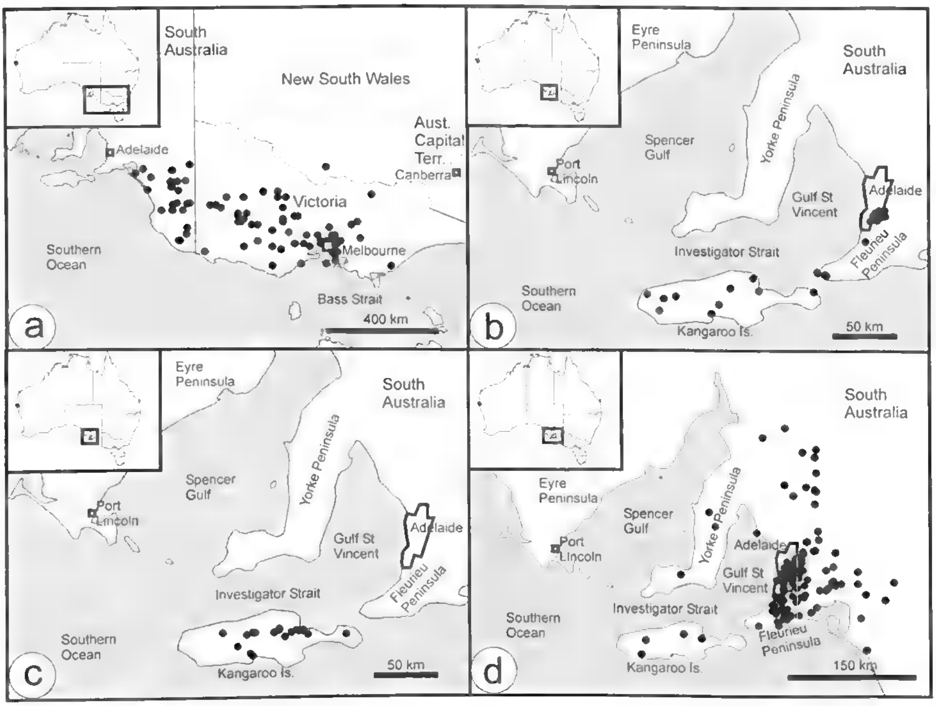

Fig. 1. Distribution maps of the *Drosera whittakeri* complex. **a,** *D. aberrans*; **b,** *D. praefolia*; **c,** *D. schmutzii*; **d,** *D. whittakeri*.

Table 1. Comparison of features for taxa within Drosera whittakeri s. lat.

Feature	*D. aberrans*	*D. praefolia*	*D. schmutzii*	*D. whittakeri*
Mature tuber colour	pale orange	white	pale orange	orange
Root length (comparative)	long	short	short	short
Root hairs	dense	few	few	few
Laterally propagating stolons	present	absent	absent	absent
Leaf emergence	before flowering	after flowering	before flowering	before flowering
Cauline leaves	absent	absent	whorled	absent
Leaf disposition	adpressed to substrate	adpressed to substrate	semi-erect	adpressed to substrate
Leaf shape	broadly spathulate	ovate to obovate	narrowly spathulate	broadly spathulate
Petiole shape in transverse section	weakly 3–5-ridged	lenticular, slightly lunate	canaliculate	strongly 5-ridged
Petiole length; base width; apex width (mm); range and mean	8–15 (12); 1–1.3 (1.2); 1.5–1.7 (1.6)	4–8 (6); 1.8–2.1 (2); 2–2.3 (2.2)	8–12 (10); 1–1.3 (1.2); 2–2.5 (2.3)	15–35 (23); 4.5–5.5 (5.1); 6–7.5 (6.9)
Petiole stalked glands	absent	present	absent	absent
Scape	absent	ubiquitous, 1, subterranean	common, 1–3, pronounced	rare, 1, short
Inflorescence position	terminal	lateral	terminal	terminal
Flowers	1–4(–7); opening successively	up to 10; multiple open together	1–7; multiple open together	up to 20; multiple open together
Sepal length × width (mm); range & mean	4–5 (4.5) × 2–4 (2.7)	4–5 (4.6) × 1.1–1.5 (1.3)	4–7.5 (5.4) × 1.3–3 (1.9)	6–8 (6.9) × 3–4 (3.6)
Sepal apex shape	entire	irregularly serrate	irregularly serrate	entire
Petal length × width (mm) ; range & mean	8–12 (11) × 5–8 (6.5)	6–9 (7.5) × 4–5 (4.4)	10–14 (12.3) × 7–9 (8)	10–12 (11.2) × 6–10 (8.8)
Petal apex shape	retuse	crenulate -retuse	retuse	truncate -crenulate
Anthers	yellow	yellow	white	white
Pollen	yellow	glassy, pale yellow	yellow	pale yellow
Stigma lobing	unlobed (single)	2-lobed	unlobed (single)	4-lobed
Stigma apex	rounded	rounded	rounded	flat
Pedicels in fruit	decumbent	decumbent, under foliage	arching	decumbent, rarely arching
Seed shape (fig. 3)	ovoid-cylindrical	ovoid	irregularly cuboid	angular ovoid-cylindrical
Seed length × width (mm) ; range & mean	1–1.3 (1.2) × 1–1.3 (1.1)	0.7–1 (0.8) × 0.4–0.8 (0.7)	1.3–1.5 (1.4) × 0.8–1.5 (1.1)	1–1.3 (1.2) × 0.7–1 (0.9)
Seed cell sculpturing (Fig. 3), terminology follows Barthlott	irregularly hexagonal with thickened anticlinal margins	irregularly hexagonal with thickened anticlinal margins	strongly irregular hexagonal with weakly thickened anticlinal margins	irregularly hexagonal with weakly thickened anticlinal margins

There have been some studies of *D. whittakeri* s. lat., mainly on nutrient-related physiology (Chandler & Andersson 1976) and pigment chemistry (Cooke & Segal 1950), but no overall examination of morphological variation throughout its distributional range. Chandler and Andersson (1976) found that vegetative propagation in Victorian *D. aberrans* (referred to as '*D. whittakeri*') was regulated by the availability of nutrients; with plants that showed above-average phosphorous levels being more likely to produce multiple, secondary tubers. This reflects the fact that these taxa, unlike many of their tuberous Western Australian counterparts, often grow on soils that are not as severely nutrient-limited (Pate & Dixon 1982). Jeffrey (1967) further found that plants in poor soils on the Ninety-Mile Plain near Keith, South Australia (here recognised as *D. aberrans*) grew embedded in and associated with the phosphate-collecting surface proteoid root mats of *Banksia ornata* F.Muell. ex Meisn. (Proteaceae). This is further supported by Clayton's (2003) observations that *D. whittakeri* s. lat. responds well to regular applications of half-strength fertilizer, unlike the majority of native Droseraceae.

Methods

Living specimens both in the field and in cultivation were examined for the characteristics listed in Table 1, as were the accessions held at AD, ADU, MEL and PERTH. This resulted in the measurement and comparison of 162 *D. whittakeri*, 105 *D. aberrans*, 38 *D. praefolia* and 35 *D. schmutzii* collections. As tuber colour intensity can vary with maturity, only fully-developed tubers from mature plants at dormancy were used for comparison.

Predictive distribution modelling used the Predicted Distribution module in Biolink 2.0.5 (Shattuck 2003) with default climatic parameters and the Gower Metric (DOMAIN) option; all known localities for *D. schmutzii*; and parameter tolerances set to 75% and 50% with contour mapping intervals of 10% and a lower cut-off of 30%.

Taxonomy

Features such as flower number (which might be expected to be influenced by environment) and seed size and shape (which can be affected by development) differ consistently across the range of materials examined, further supporting their segregation as separate species (Table 1). Four species are here recognised within *Drosera whittakeri* s. lat.

Key to species in *Drosera whittakeri* s. lat.

1 Leaves emerging before flowering; inflorescence terminal 2

1* Leaves emerging after flowering; inflorescence lateral .... ***D. praefolia***

2 Plants stoloniferous; flowers few, opening in succession .... ***D. aberrans***

2* Plants not stoloniferous; flowers numerous, several opening together 3

3 Leaves narrowly canaliculate-petiolate, cauline leaves whorled .... ***D. schmutzii***

3* Leaves obovate, flat, tapering basally, cauline leaves absent .... ***D. whittakeri***

Drosera aberrans (Lowrie & Carlquist) Lowrie & Conran, ***comb. & stat. nov.***

D. whittakeri subsp. *aberrans* Lowrie & Carlquist, *Phytologia* 73(2): 98, 113 & 115 - Fig. 8 (1992); F.Muell. *The Native Plants of Victoria Succinctly Defined*, p. 53 (1879) (as '*D. whitackeri*')

Type: South Australia: in red loam soils in mallee scrub country west and east of Sherlock, 19 July 1991, *D.E. Murfet 1059* (holo: PERTH; iso: RSA).

Illustrations: Mueller (1879) Fig. 10; Lowrie & Carlquist (1992) Fig. 8; Lowrie (1998: 257); Lowrie (1998: 259 photos).

Perennial *herb*, colony-forming, tuberous, stoloniferous, green, orange-yellow or red, with leafy rosette, 3–5 cm diam. *Tuber* pale orange, ± broadly obovoid, c. 8 mm long, c. 8 mm diam., enclosed in a number of black papery sheaths at the end of a vertical subterranean stem 4–5 cm long. *Leaves* broadly spathulate, adpressed to soil surface, often turning redder with age, with 8–12 leaves per rosette; petiole 8–15 mm long, 1–1.3 mm wide at base, dilated to 1.5–1.7 mm wide distally (at base of lamina), longitudinally weakly 3–5 ridged, margin entire, glabrous; *lamina* obovate to broadly obovate, 5–11 mm long, 6–11 mm wide, length and width commonly variable within same rosette, margin basally entire, distally dentate, with apex dentate (more readily observed on abaxial surface), with glandular trichomes terminating each apical dentate marginal segment, insect-catching glands positioned on adaxial surface near margin of lamina, with slightly shorter glands medially, trichomes green to translucent red with dark red glandular heads, abaxial lamina glabrous, veins branched towards apex (more readily observed in dried specimens). *Inflorescence* consisting of 1–4 (rarely to 7) flowers arising from centre of rosette and opening singly in succession, pedicels ± similar in colour to leaves, 1–4 cm long, sparsely covered with scattered sessile glands, pedicels decumbent in fruit. *Sepals* green to reddish, lanceolate, 4–5 mm long, 2–4 mm wide, margin entire, apex entire, abaxial surface black dotted (more easily observed in dried specimens), with small number of scattered minute sessile glands similar to those found on scape, otherwise glabrous. *Petals* white, cuneate, margin entire, apex retuse, 8–12 mm long, 5–8 mm wide. *Stamens* 5, 4–4.5 mm long, filaments white, anthers yellow, pollen yellow. *Ovary* green, obovoid, 1.7–2 mm long, 1.6–1.9 mm diam. *Styles* and *stigmas* 3, white, 1.6–1.8 mm long, each divided into many filiform branching segments, glabrous, stigmatic portion white, slightly dilated apically into a single, rounded, knob-like projection, papillose. *Seed* charcoal black, ovoid-cylindrical, 1–1.3 mm long, 1–1.3 mm diam., surface sculpture irregularly hexagonal with thickened anticlinal margins; micropyle within indented basal pole, apical pole rounded. (Figs 2a, b & 3a, b)

Habitat: common in a wide range of soil types from sands to lateritic gravels and limestone-derived clays. The plants grow in full sun or partial shade in mallee woodlands, heaths and open forested regions.

Distribution: widespread across the inland southern mallee regions of South Australia east of the Mount Lofty Ranges, southern and central Victoria to east of Wilson's Promontory. A single collection is reported from southern central New South Wales (Fig. 1a).

Conservation status: common and well represented in conservation areas. Not threatened.

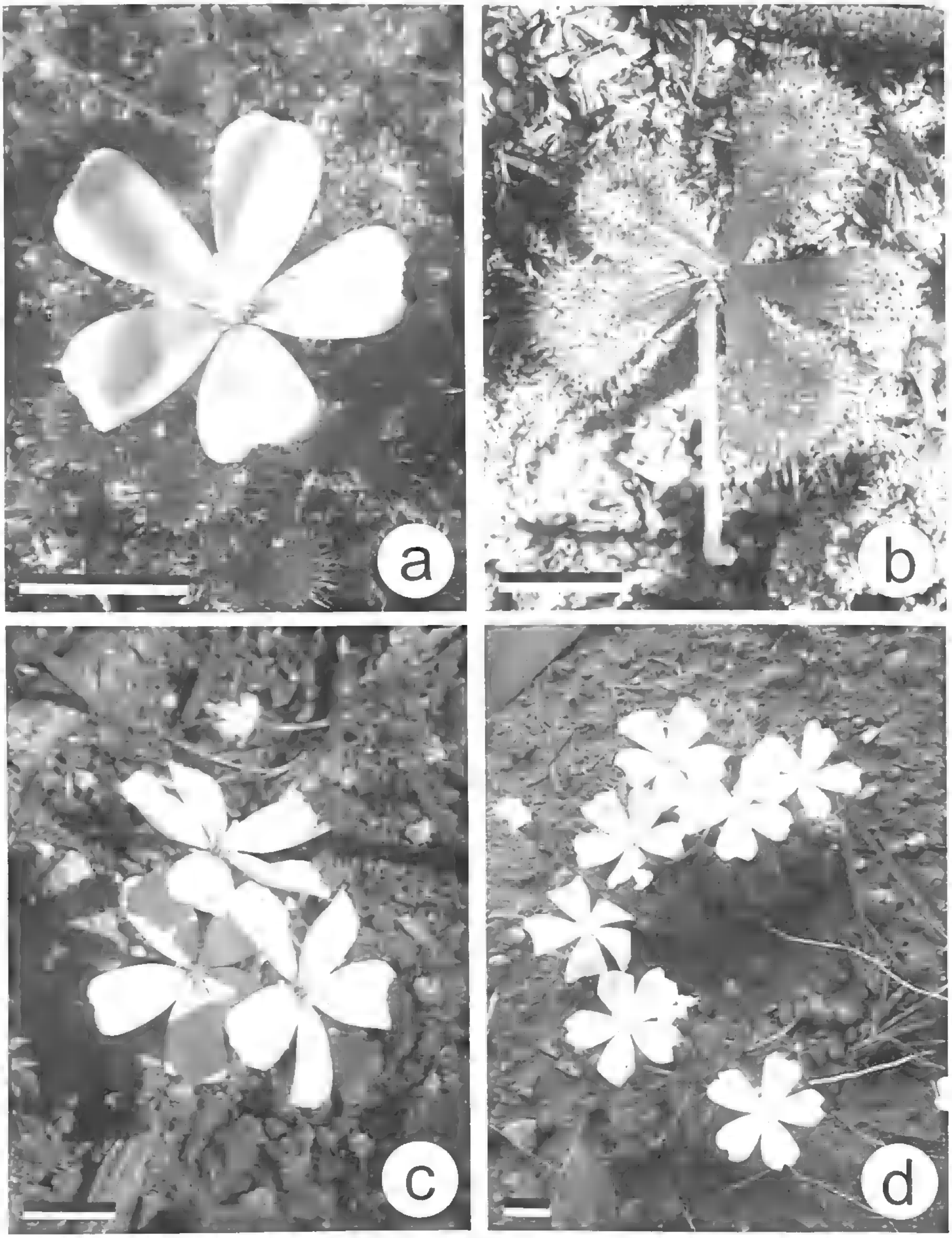

Fig. 2. Members of *Drosera whittakeri* Planch. complex other than *D schmutzii*, showing distinctive characteristics. **a,** *D. aberrans* (Lowrie & S. Carlquist) Lowrie & Conran, habit with typically 1-flowered plant (*Conran 2014*); **b,** same showing lateral stolons (*Conran 1563*); **c,** *D. praefolia* Tepper with precocious lateral inflorescence emerging before the leaves (*Conran 1972*); **d,** *D. whittakeri* with robust, simultaneously multi-flowered habit (*Conran 1971*). Scale bars 10 mm.

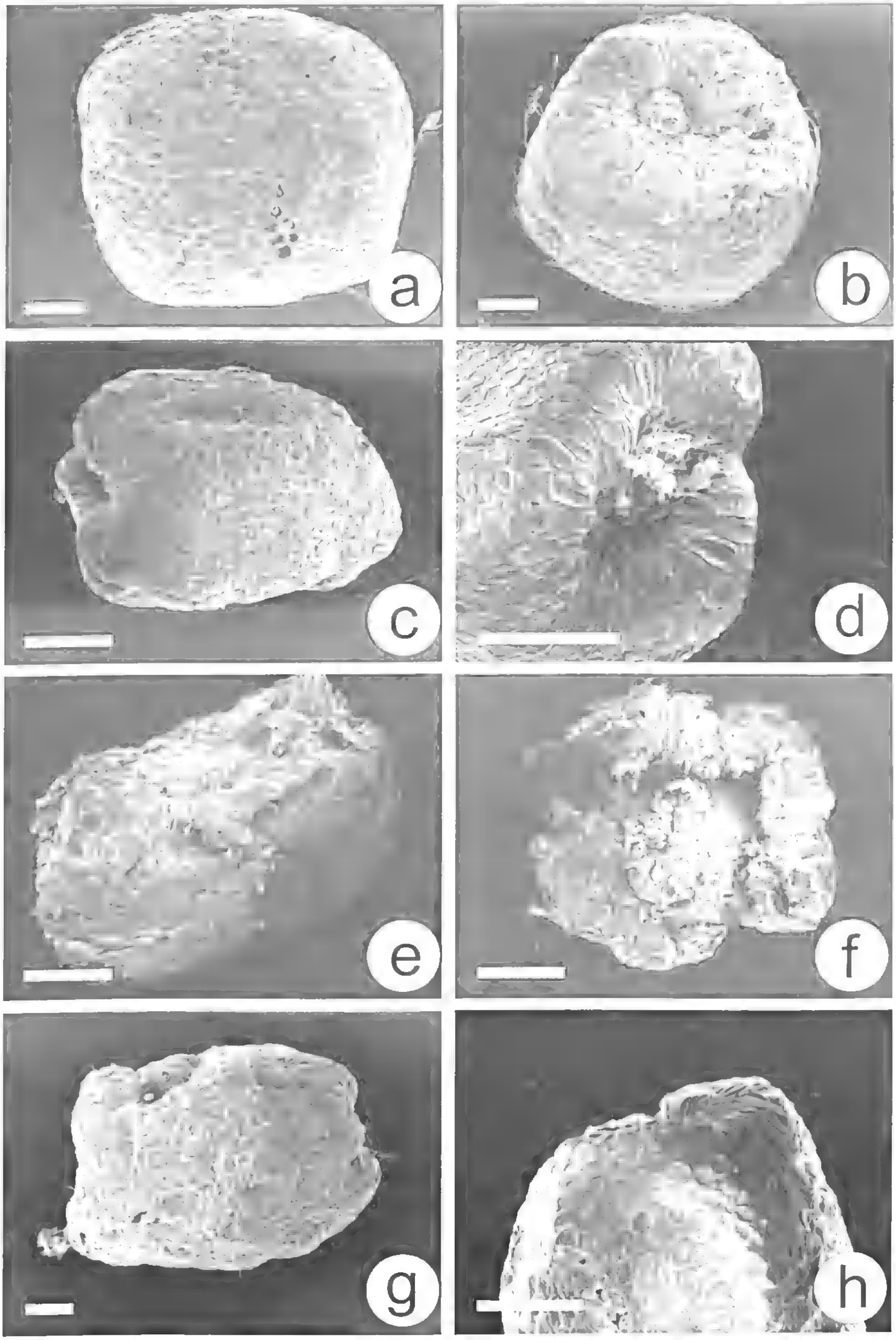

Fig. 3. Seeds of the *Drosera whittakeri* complex. **a,** *D. aberrans* (*Lowrie 2836*) lateral view; **b,** micropylar view; **c,** *D. praefolia* (*Conran 1972*) lateral view; **d,** micropylar view; **e,** *D. schmutzii* (*Conran 1525*) lateral view; **f,** micropylar view; **g,** *D. whittakeri* (*Lowrie 2831*) lateral view; **h,** micropylar view. Scale bars 200 µm.

Notes: *Drosera aberrans* flowers July–September and has a dry dormancy period as a subterranean tuber over summer. The species regularly multiplies asexually, producing axillary stolons that occur along the vertical subterranean stem and frequently from the centre of the parent rosette. These stolons develop above the soil surface until clear of the parent plant, and then burrow into the soil where additional tubers are produced. As a result of this stoloniferous propagation, large, mat-like, compact colonies of rosettes are produced. Possibly because of this, not many flowers are produced in most years, a single colony of several hundred ramets often only making a few flowers per season, and generally only 1–4 per flowering shoot, although plants on more fertile soils may produce more flowers (rarely up to seven per plant) and more regularly. Unlike the other species described here, the flowers appear to open singly in succession on each shoot. The scent is (subjectively) sweet and similar to *D. schmutzii,* but differing from *D. praefolia* and *D. whittakeri.* Leaf colour does not appear to be a function of exposure, as green, orange and red-leaved forms grow together at many sites as adjacent uni-coloured colonies, both in shade and full sun, and maintain these colours under uniform cultivation conditions (pers. obs.), although leaves also tend to become more red with age.

Mueller (1879) illustrated this taxon (as *D. whitackeri* [sic]) with two rosettes arising from a single, branched vertical shoot arising from the tuber, but there are no specimens at MEL or anywhere else that appear to show this and this may represent artistic licence.

Although the ranges of *D. aberrans* and *D. whittakeri* do overlap briefly at the Coorong National Park and Monarto Conservation Park, SE of Adelaide, there is no evidence of intermediate specimens.

Selected specimens examined: New South Wales: Edward River. Riverina (35°31'S 144°55'E), *Sullivan s.n.*, 1876 (MEL96947A). **South Australia**: Coorong National Park (36°11'32"S, 139°40'39"E), *Robinson 1480 & Casperson*, 8 Jul 1987 (AD98807443); Bangham Conservation Park (36°36'0"S, 140°54'0"E), *Murfet 1605*, 3 Oct 1992 (AD99249185); Malinong Scrub (35°33'58"S, 139°32'35"E), *Murfet 3875, Taplin & Eckert*, 3 Aug 2001 (AD123197); EP 150 Nangwarry (37°32'37"S, 140°48'56"E), *Wilson, 829*, 1 Jul 1968 (AD96936147); North Horseshoe Native Forest Reserve (37°20'S, 140°50'E), *Meznar 2*, 15 Aug 1984 (AD98520133); Wirrega Railway Station (36°12'25"S, 140°34'54"E), *Osborn s. n.*, 2 Oct 1915 (AD97618594); Mount Watch, The Bluff (37°43'40"S, 140°34'12"E), *Lothian 2912*, 26 Aug 1964 (AD96511062); Wright Swamp Road (38°4'S, 141°20'E), *Dodson 14211*, 19 Sep 1972 (AD97241164); Monarto Conservation Park, Kangaroo Flat Road (35°10'04"S 139°07'28"E), *Lowrie 2836* & *Murfet*, 9 Sep 2003 (AD, PERTH, MEL); University of Adelaide research campsite, Mount Rescue Conservation Park (35°56'56.8"S 140°21'36.8"E), *Conran 1563*, 18 Sep 2004 (AD, ADU). **Victoria:** Ringwood, Melbourne by railway line 1 km E of station (37°49'S 145°15'E), *Muir 793*, 22 Aug 1959 (MEL96919A); You Yangs (37°57'S 144°25'E), *Walter s.n.*, Aug 1900 (MEL96928A); Wangaratta (36°21'S 146°19'E), *Collector unknown*, 24 Jul 1907 (MEL96934A); Anglesea, *Le Breton s.n.*, 27 Aug 1976 (MEL234071A); Beaufort (37°25'S 143°22'E), *Audas s.n.*, 1898 (MEL566358A); Mount Arapiles, near summit (36°45'S 141°50'E), *Conn s.n.*, 9 Jul 1973 (MEL1546717A); Along Stoney Creek track, Grampians Wonderland (37°8'S 142°31'E), *Marks 15*, 24 Aug 1987 (MEL1559957A); 12 km NNW of Dunolly (36°46'S 143°41'E), *Beauglehole, 64756 & Maryborough Field Naturalist's Club*, 9 Sept 1979 (MEL1577737A); Brisbane Ranges National Park, McLeans Highway, E of Switchback Road Junction, 6.5 km N of Anakie (37°52'S 144°15'E), *Beauglehole 56600, A. & Errey*, 1 Oct 1977 (MEL1577744A); Point Nepean National Park, Greens Bush, bounded by Rogers and Greens Roads. Grid Ref.: CT193430 - CT194448 (38°26'S 144°55'E), *Connock 113*, 17 Aug 1990 (MEL1592726A).

Drosera praefolia Tepper, *Bot. Centr.* 50: 357 (1892)

D. bulbosa Hook. var. *praefolia* (Tepper) R.Hamet, *Bull. Soc. Bot. France* 54: 70 (1907)

D. whittakeri var. *praefolia* (Tepper) J.M.Black, *Fl. S. Aust. Pt 2*, 258 (1924)

D. whittakeri subsp. *praefolia* (Tepper) Lowrie, *Bull. Austral. Carniv. Pl. Soc.* 8: 47 (1989)

D. aphylla Tepper ex R.Bates, *J. Adelaide Bot. Gard.* 14: 99 (1991) *nom. illeg.*

Type: "Im August 1881 langte ich in Clarendon an, um das Dorf für einige Zeit zu meinem Wohnsitze zu machen. Vorher war ich für einige Jahre im nordöstlichen Theile von Yorke's peninsula [Clarendon, Mount Lofty, South Australia, *Tepper 618*]" (holo: MEL).

Illustrations: Lowrie (1998: 217); Lowrie (1998: 219 photos).

Perennial *herb*, solitary, tuberous, green, or sometimes red (in full sunshine), with a leafy rosette, 4–6 cm diam.. *Tuber* white, ± globose, 6–8 mm long, 6–8 mm diam., enclosed in a number of black papery sheaths at the end of a vertical subterranean stem 3–5 cm long. *Leaves* obovate, absent at anthesis, adpressed to soil surface, with 8–16 leaves per rosette; petiole 4–8 mm long, c. 2 mm wide at base, slightly dilated distally at base of lamina, lenticular and slightly lunate in section on the upper leaves, less so on the lower leaves, margins slightly revolute, glandular; vernation involute; *lamina* ovate to obovate, 10–16 mm long, 8–12 mm wide, length and width commonly variable within the same rosette, margin entire, distally dentate with apex dentate (more readily observed on abaxial surface), with glandular trichomes terminating each apical dentate marginal segment, insect-catching glands positioned on adaxial surface near margin of lamina, with slightly shorter glands medially, trichomes green to translucent red with dark red glandular heads, abaxial lamina glabrous, veins branched towards apex (more readily seen in dried specimens). *Inflorescence* a lateral, subterranean scape emerging prior to the leaves. *Flowers* up to 10, terminal on scape, pedicels green to red, 2.5–5 cm long, sparsely covered with scattered sessile glands, pedicels decumbent and ± underneath leaf rosette in fruit. *Sepals* reddish, narrowly ovate to lanceolate, 4–5 mm long, 1.1–1.5 mm wide, margins entire, apex irregularly serrate, abaxial surface black dotted (more easily seen in dried specimens), glabrous. *Petals* white, cuneate, margins entire, apex crenulate-retuse, 6–8 mm long, 3–4 mm wide. *Stamens* 5, 3–3.5 mm long, filaments white, anthers yellow, pollen glassy, pale-yellow. *Ovary* green, obovoid, 1–1.2 mm long, 1–1.2 mm diam. *Styles* and *stigmas* 3, white, 1.2–1.4 mm long, each divided into many filiform branching segments, glabrous, stigmatic portion white, apically 2-lobed, slightly dilated, papillose. *Seed* charcoal black, ovoid, 0.7–1 mm long, 0.4–0.8 mm diam., micropyle within indented basal pole, apical pole rounded, surface sculpture irregularly hexagonal with thickened anticlinal margins. (Figs 2c & 3c, d)

Habitat: the species generally grows in exposed, dry sites or open woodland on loams, decomposed shales or lateritic clay-sand. It flowers in moderate shade as well as full sun and does not need fire to trigger flowering.

Distribution: *Drosera praefolia* occurs in south-east South Australia along the southern Fleurieu Peninsula south of Adelaide, extending to Kangaroo Island. (Fig. 1b)

Conservation status: well represented in conservation areas and not considered to be threatened, despite its relatively narrow distribution.

Notes: the species flowers April–May, often shedding its seeds before leaf production, and has a dry dormancy period as a subterranean tuber over summer. Leaf colour varies from green to red in this species, but unlike *D. aberrans* and *D. whittakeri*, redder leaves seem to be more a response to exposure to sunlight.

Although described by Tepper (1892) from material he collected on the Fleurieu Peninsula near Adelaide, the species was largely ignored, or regarded as a poorly known, precocious-flowering variant of *D. whittakeri* (Marchant et al. 1982, Marchant 1986), despite the very detailed account of its form and phenology sent by Tepper to Mueller in 1882 along with specimens (correspondence held at MEL). Mueller annotated the sheets as *D. whittakeri* var. *aphylla*, but the name was never published, nor did Mueller adopt Tepper's name. Bates (1991) demonstrated clearly that *D. praefolia* is distinct from *D. whittakeri* s. lat. by: its white tuber; habit of flowering on a lateral inflorescence before leaves emerge; and the possession of obovate, elliptic and/or orbicular leaves within the same rosette, 2-lobed stigmas and the highly unusual (for the family) involute leaf vernation. Nevertheless, despite being recognised at subspecific (Lowrie 1989) and later, specific rank (Gibson 1995, Lowrie 1998, CHAH 2006), *D. praefolia* continues to be regarded as part of *D. whittakeri* by some authors (e.g. Barker et al. 2005, Schlauer 2006). However, its numerous differences from the other species described here strongly support its recognition at species rank.

Selected specimens examined: South Australia: Talisker Conservation Park along walking trail near trig point and car park (35°37'0"S, 138°9'18"E), *Duval 488 & Te, Millenium Seed Bank Partnership*, 19 Jun 2006 (AD198072); SA Water, Mount Bold Reservoir land off Scenic Road, Clarendon (35°6'57"S, 138°40'0"E), *Robertson 225*, 22 Apr 1999 (AD99917188); From scrubland 2 miles [3.2 km] to the ENE of Clarendon (35°6'1"S, 138°39'37"E), *Nash, s.n.*, 27 May 1967 (AD96725303); Approximately 2.3 miles [3.7 km] due W of Clarendon (35°6'41"S, 138°34'23"E), *Nash, s.n.*, 9 Apr 1967 (AD96717033); In scrubland at Cherry Gardens, c. 22 km SSE of Adelaide (35°3'55"S, 138°39'55"E), *Smith, 1856*, 28 Apr 1972 (AD97413171); Onkaparinga National Park (35°8'33"S, 138°35'16"E), *Murfet 3163*, 9 Apr 1998 (AD99906226); Deep Creek Conservation Park (35°38'S, 138°10'E), *Murfet 1036b & Taplin*, 20 May 1991 (AD99134053); 2 km E of Cape Jervis (35°36'S, 138°5'E), *Bates 16892*, 10 Apr 1989 (AD99032067); Top of Willunga Hill (35°20'S, 138°30'E), *Bates 17555*, 10 May 1989 (AD99032066); 6.65 km NW of Cape St. Albans Lighthouse (35°46'53"S, 138°3'24"E), *Overton, Canty & Kinnear, S. A. NPWS Kangaroo Island Survey, NPKI40873*, 19 Nov 1989 (AD99026189); 8.5 km NE of Parndana (35°44'55"S, 137°20'17"E), *Croft & Dennis, S. A. NPWS Kangaroo Island Survey, NPKI40038*, 13 Nov 1989 (AD99026187); On track into Gosse Crown Lands from Playford Highway about 2.5 miles [4 km] S of highway (35°49'10"S, 136°52'0"E), *Jackson 1516*, 12 Apr 1982 (AD98231202); 9.5 km from Cape Borda Road, on West Bay Ravine Track, W side of track (35°48'S, 136°37'E), *O'Leary 2594*, 24 Apr 1992 (AD99233265); Mount McDonnell area near radio towers (35°37'46"S, 137°18'47"E), *Murfet 5349*, 20 Aug 2006 (AD199083); Rex Ellis'property, Hundred of Borda (35°50'19http://www.vinodiversity.com/viticulture-and-environment.htmlS, 136°45'38"E), *Jackson 1522*, 26 Apr 1982 (AD98231196); Wittow Creek, 1. 75 km S of East West Highway II, 0. 5 km W of Hickmans Road. Section 12, Hundred of Seddon (35°53'20"S, 137°14'0"E), *Overton 1532*, 5 Jul 1991 (AD99143016); 7 km W of Rocky River Park H. Q. Rocky River floodplain (35°56'54"S, 136°43'39"E), *Robinson & Halstead, S. A. NPWS Kangaroo Island Survey, NPKI10547*, 7 Nov 1989 (AD99026183); From paddock behind Old Cemetery, Kingscote (35°39'21"S, 137°38'8"E), *Jackson 615*, 10 May 1969 (AD96949048); Vivonne Bay, S coast. 750 m E of Harriet River bridge, 50 m S of South Coast Road (35°58'0"S, 137°10'50"E), *Overton 1912*, 3 May 1992 (AD99223013); Beyeria Conservation Park, W boundary, Willsons Road, 3 km E of Hundred Line Road (35°46'S, 137°35'E), *Overton 1941*, 22 May 1992 (AD99232117); Piggot Range Road, Southern Mount Lofty Ranges (35°8'9.2"S 138°35'13.1"E), *Conran 1972*, 5 Jul 2006 (AD, ADU).

Drosera schmutzii Lowrie & Conran, ***sp. nov.***

Affinis *Drosera whittakeri* sed saepe breviter caulina. Folia rosularia spathulata petiolata et folia caulina verticillata (*D. stolonifera* similis); petioli angusti canaliculati. Petala obovata, truncata, alba, 10–14 mm longa, 7–9 mm lata. Semina nigra, oblonga-irregularis, ruminata-reticulata, ad apicem et basi indenta, 1.3–1.5 mm longa, 1.2–1.5 mm × 0.8–0.9 mm lata.

Type. South Australia: corner of South Coast Road and Elsegood Road, *c.* 20 km south of Kingscote, Kangaroo Island (35°46'11"S, 137°33'34"E), 6 Sep 2003, *A. Lowrie 2816 & D.E. Murfet* (holo: AD; iso: PERTH, MEL).

Perennial *herb*, solitary, tuberous, green to red, with a leafy rosette, 3–4 cm diam. at anthesis. *Tuber* pale orange, ± broadly obovoid, c. 8 mm long, c. 8 mm diam., depressed laterally, enclosed in a number of dark brown papery sheaths at the end of a vertical subterranean stem 4–5 cm long. *Leaves* narrowly spathulate, few leaves adpressed to the soil surface, most semi-erect, a second distal leaf whorl often present on a stem c. 10 mm long (resembling the leaves of *D. stolonifera*), with 8–10 leaves per rosette; petioles 8–12 mm long, 1–1.3 mm wide at base, dilated to 2–2.5 mm wide distally at base of lamina, adaxially canaliculate in section on distal leaves, less so on basal leaves, longitudinally ridged, margins entire, glabrous; *lamina* obovate to broadly obovate, 5–9 mm long, 6–11 mm wide at anthesis, length and width of lamina commonly variable within same rosette, longitudinally depressed adaxially for two thirds, distal lamina often incurved-lunate (resembling *D. stolonifera* leaves), basal margins entire, distal margins dentate with apex dentate (more readily observed on abaxial surface), with glandular trichomes terminating each apical dentate marginal segment, insect-catching glands positioned on the adaxial surface near margin of lamina with slightly shorter glands medially, trichomes translucent red with dark red glandular heads, abaxial lamina glabrous, veins branched towards the apex (more readily observed in dried, blackened specimens). *Inflorescence* consisting of 1–3 terminal, short to elongated scapes, or flowers ± arising from the centre of the rosette. *Flowers* usually 2–7, pedicels ± similar in colour to leaves, 2.5–4 cm long, sparsely covered with scattered sessile glands, pedicels arching downwards in fruit. *Sepals* reddish, narrowly ovate to lanceolate, 4–7.5 mm long, 1.3–3 mm wide, margins entire, apex a little irregularly serrate, abaxial surface black dotted (more easily observed in dried specimens), with a small number of scattered minute sessile glands similar to those found on the scape, otherwise glabrous. *Petals* adaxial and abaxial surface white, obovate, margin entire, apex retuse, 10–14 mm long, 7–9 mm wide. *Stamens* 5, 3–3.5 mm long, filaments white, anthers white, pollen yellow. *Ovary* green, obovoid, 1.2–1.5 mm long, 1.2–1.3 mm diam. *Styles* and *stigmas* 3, white, 1–1.5 mm long, each divided into many filiform branching segments, glabrous, stigmatic portion white, slightly dilated apically into single knob-like projection, papillose. *Seed* charcoal black, irregularly cuboid, sides ± flattened, 1.3–1.5 mm long, 1.2–1.5 mm wide, 0.8–0.9 mm thick, micropyle small, ± hidden within an indented basal pole, apical pole indented, surface sculpture strongly irregular hexagonal, with weakly thickened anticlinal margins. (Figs 3 e, f; 4 & 5)

Etymology: the Latinised epithet *schmutzii* honours Father Erwin Schmutz SVD (Society of the Divine Word) of the German Catholic Centre, Collinswood South Australia who discovered this species. He is an accomplished and passionate field naturalist of flora, fauna and geology in Indonesia and South Australia.

Habitat: *Drosera schmutzii* commonly grows in buff-yellow sandy clay with laterite

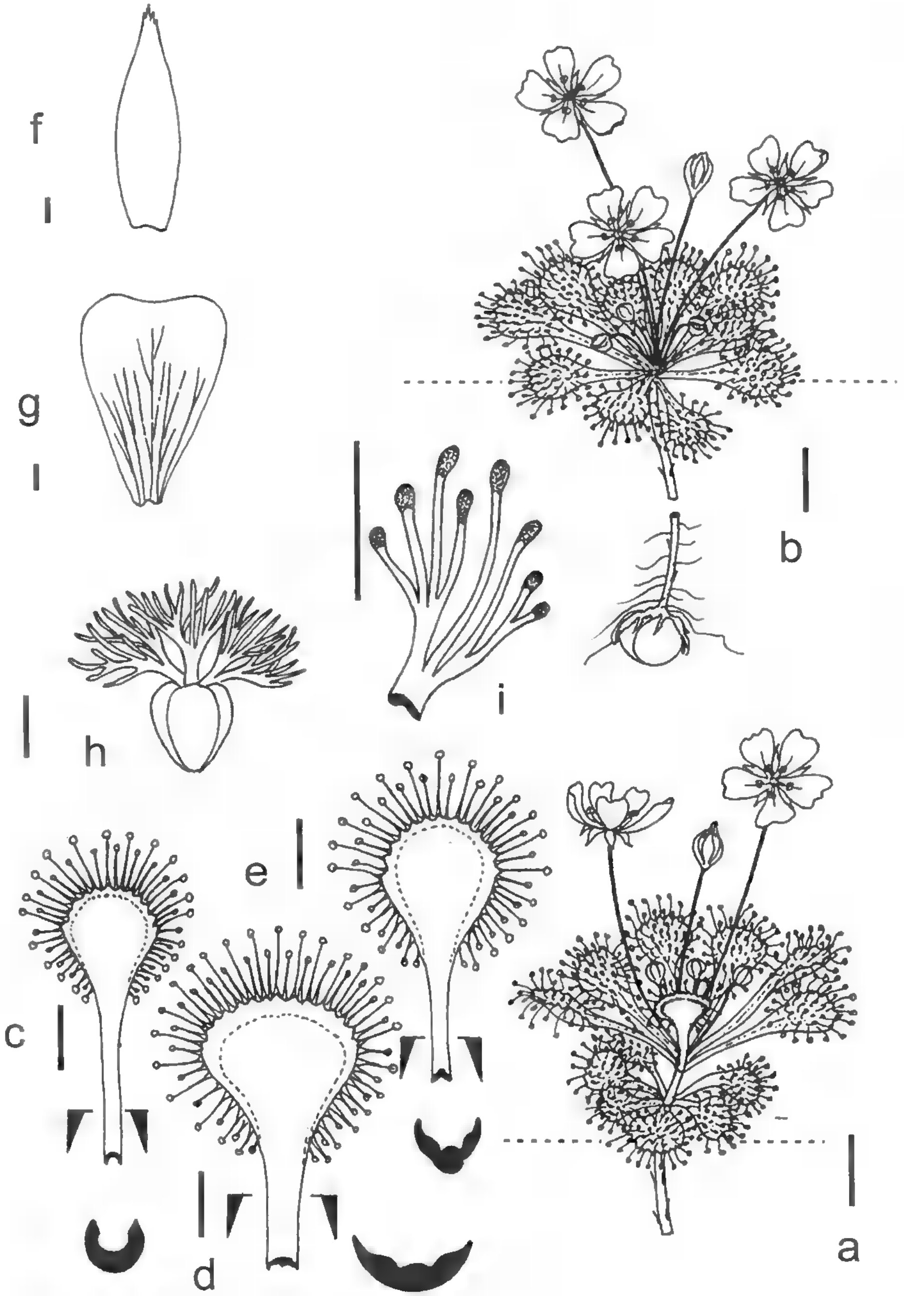

Fig. 4. *Drosera schmutzii* Lowrie & Conran. **a,** plant showing whorled distal leaves on stem; **b,** plant; **c,** cauline lamina; **d,** proximal basal rosette lamina; **e,** distal basal rosette lamina; **f,** sepal; **g,** petal; **h,** ovary and styles; **i,** style-stigmas, enlarged. Scale bars 10 mm (a, b), 5 mm (c–e), and 1 mm (f–i). Drawn by A. Lowrie from live material collected from the type location (*A. Lowrie 2816 & D.E. Murfet*)

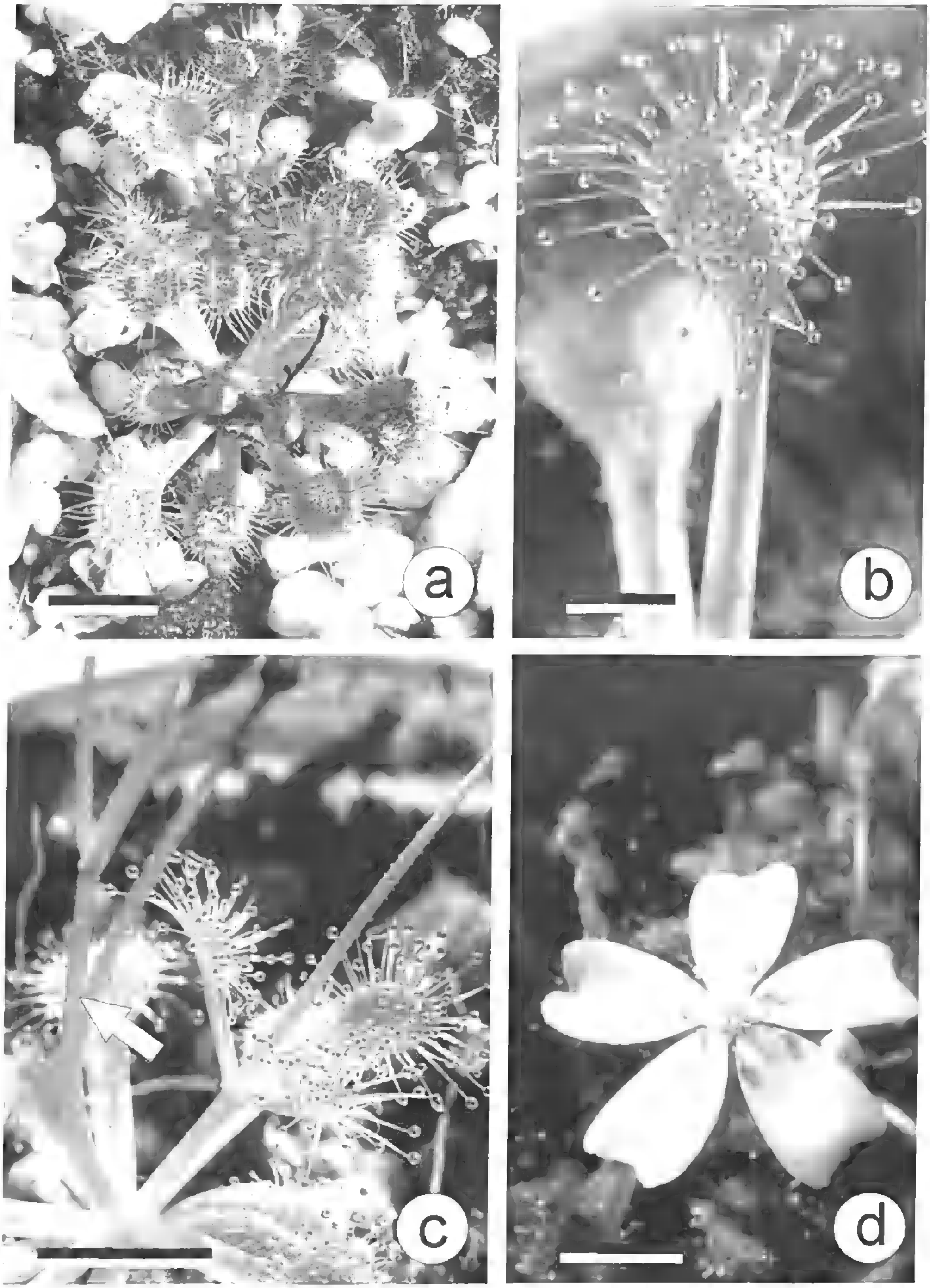

Fig. 5. *Drosera schmutzii* (*Conran 1525*). **a,** habit; **b,** leaf showing narrow, semi-erect, canaliculate petiole; **c,** whorled cauline leaves and flowering scape (arrow); **d,** flower. Scale bars 10 mm (a, c, d) and 2 mm (b).

pebbles, with the underlying rock sandstone, in open sunny areas amongst *Allocasuarina muelleriana* (Miq.) L.A.S.Johnson (Casuarinaceae). It has also been found on red, iron- and aluminium-rich clay with iron-rich, pisolith (pea-like) gravels; Macgillvray white sands (derived from dune sands) with laterite intrusions; and in sandy soils in small shallow gnamma holes in sheet limestone cap rock overlooking the ocean. The species often grows with another Kangaroo Island endemic: *Stylidium tepperianum* (F.Muell.) Mildbr. (Stylidiaceae). All of these habitats are dry in summer.

Distribution: *Drosera schmutzii* is a Kangaroo Island endemic that occurs across the island, but seems to be mainly in the northern and eastern areas (Fig. 1c). It occurs along the N and E boundaries of the Flinders Chase National Park, but does not seem to be widespread inside the park, although this may represent lack of collecting.

Conservation status: although common across the island and not immediately threatened, the majority of collections have been from areas that are subject to human impact (e.g. along roadsides) or are not in reserves.

Notes: the species flowers from late June to September and has a dry dormancy period as a subterranean tuber over summer. Leaf colour varies from green to red in this species, but unlike *D. aberrans* and *D. whittakeri*, redder leaves seem to be a response to exposure to sunlight.

Drosera schmutzii is distinguished by its very narrow, canaliculate, eglandular petioles (Fig. 5b); semi-erect leaves (Fig. 5a, c) and frequent presence of whorled leaves on a short axis (Fig. 5c), resembling the leaves of *D. stolonifera* Endl. It is further distinguished by its larger, irregularly cuboid seeds with very irregular testal sculpturing (Fig. 3e–f). These characteristics, as well as the differences noted between the other members of the *D. whittakeri* complex were consistent across the material examined, as well as for specimens grown under cultivation for several years by both authors. Even though there is some geographic and/or habitat overlap between the different taxa, at those few places where two or more of the complex co-occur there was no evidence in intergradations between them.

It was at first thought that another larger, many-leaved, rosette-forming, multi-flowered taxon, related to the *Drosera whittakeri* complex occurred on Kangaroo Island (in addition to *D. whittakeri, D. schmutzii* and *D. praefolia).* However, while it occurs frequently on the island, it proved to be just a very robust form of *D. schmutzii* when grown in cultivation, apparently analogous to the robust forms of *D. whittakeri* s. str. from the Adelaide Hills. Although *D. schmutzii* grows in a range of habitats across the island, and often co-occurs with *D. praefolia*, it is only very rarely found growing with *D. whittakeri* (Clayton 2003 and pers. obs. by both authors).

Climatic predictive distribution modelling at 75% tolerance (Fig. 6a) shows that the species is effectively confined to Kangaroo Island, with only possible extensions to the southernmost Fleurieu and Yorke Peninsulas under the 50% tolerance model (Fig. 6b). However, extensive searches in these areas failed to find any plants resembling *D. schmutzii* and in any case, *D. whittaker*i s. lat. is almost completely absent from the Yorke Peninsula.

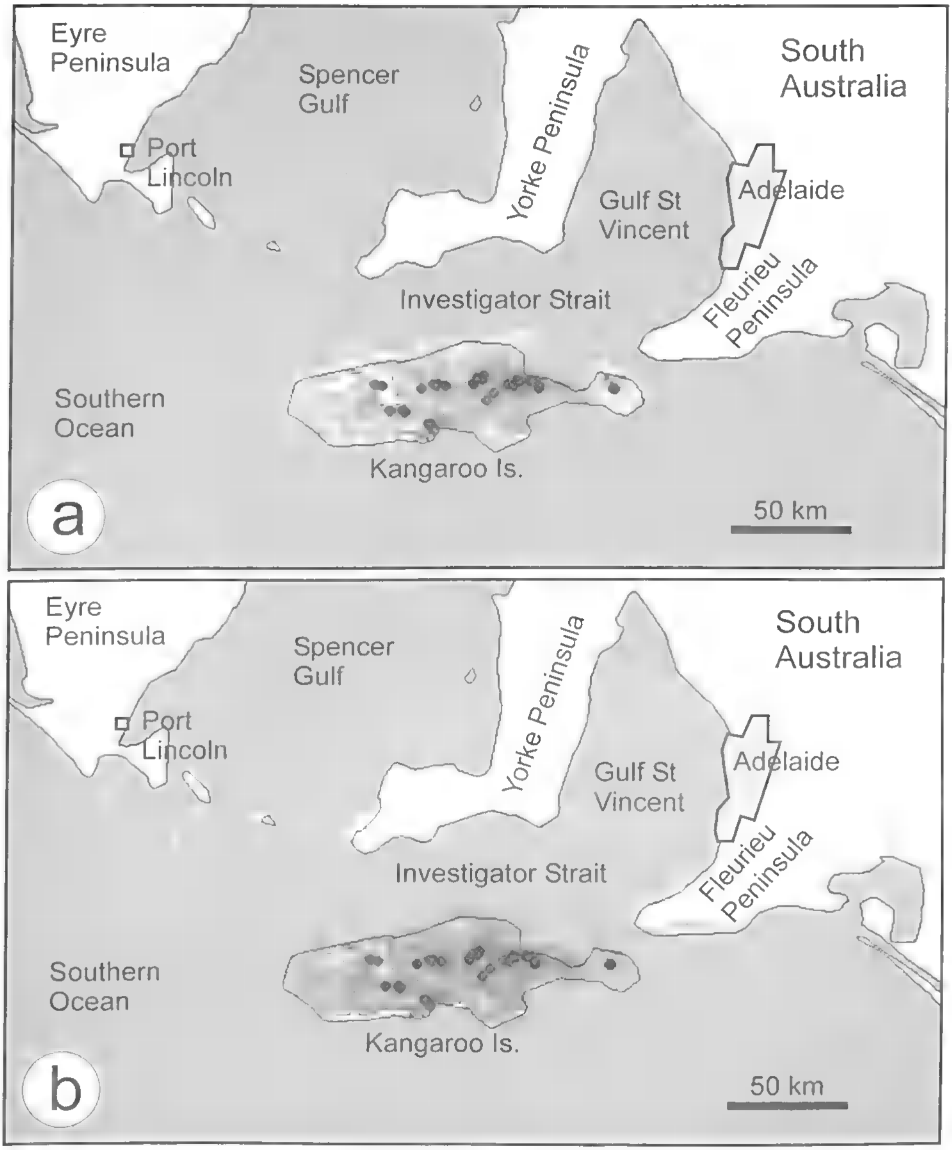

Fig. 6. Predictive distribution modelling for *Drosera schmutzii* using BIOLINK. **a,** distribution pattern under 75% tolerance; **b,** model under 50% tolerance. Darker areas are those with higher predicted probability of occurrence.

Selected specimens examined: South Australia: Kangaroo Island: South Coast Road, 24 Sep 2002, *Schmutz 8051* (AD, PERTH, MEL); Moffartt Road (35°48'12"S 137°59'19"E), *Lowrie* 2804 & *Murfet*, 6 Sep 2003 (AD, PERTH, MEL); Hog Bay Road (35°47'45"S 137°39'22"E), *Lowrie 2807 & Murfet*, 6 Sep 2003 (AD, PERTH, MEL); South Coast Road, Emu Ridge (35°47'36"S 137°32'28"E), *Lowrie 2815* & *Murfet*, 6 Sep 2003 (AD, PERTH, MEL); Junction of South Coast Road & Elsegood Road (35°46'11"S 137°33'34"E), *Lowrie 2816* & *Murfet*, 6 Sep 2003 (AD, PERTH, MEL); Junction of South Coast Road & Bark Hut Road (35°44'53"S 137°24'18"E), *Lowrie 2817* & *Murfet*, 7 Sep 2003 (AD, PERTH, MEL); Playford Highway (35°45'17"S 137°23'45"E), *Lowrie 2818* & *Murfet*, 7

Sep 2003 (AD, PERTH, MEL); Playford Highway (35°46'42"S 137°21'45"E), *Lowrie 2819* & *Murfet*, 7 Sep 2003 (AD, PERTH, MEL); Playford Highway, junction of McHughes Road (35°47'17"S 137°11'43"E), *Lowrie 2820* & *Murfet*, 7 Sep 2003 (AD, PERTH, MEL); Mount Stockdale Road (35°54'34"S 137°03'25"E), *Lowrie 2823* & *Murfet*, 7 Sep 2003 (AD, PERTH, MEL); Vivonne Bay, hill above jetty area (35°59'49"S 137°11'01"E), *Lowrie 2825* & *Murfet*, 7 Sep 2003 (AD, PERTH, MEL); Vivonne Bay, Rees Airstrip, South Coast Highway (35°57'59"S 137°10'05"E), *Lowrie 2827* & *Murfet*, 7 Sep 2003 (AD, PERTH, MEL); Birchmoor Road (35°49'20"S 137°27'12"E), *Lowrie 2829A* & *Murfet*, 7 Sep 2003 (AD, PERTH, MEL); Hog Bay Road, 14 km E of Kingscote turnoff (35°46'21.0"S 137°37'33.4"E), *Conran 1525*, 28 Jun 2004 (AD, ADU); Corner of Halls Road and road to Kingscote, Kangaroo Island (35°46'21.4"S, 137°37'34.2"E), 20 Jul 2006, *Conran 1990 & Duggan* (AD, ADU); Playford Hwy, 22.5 km SW of Kingscote, Kangaroo Island (35°46'21.4"S, 137°37'34.2"E), 20 Jul 2006, *Conran 1991 & Duggan* (AD, ADU); 2 km W of Parndana on Playford Hwy, Kangaroo Island (35°47'20.6"S, 137°14'00.0"E), 20 Jul 2006, *Conran 1994 & Duggan* (AD, ADU); 2.5 km W of Gosse Richie Road turnoff, 27.5 km W of Parndana, Kangaroo Island (35°47'49.3"S, 136°57'04.3"E), 20 Jul 2006, *Conran 1998 & Duggan* (AD, ADU); c. 9.5 km N of S Coast Hwy along Gosse Richie Road, Kangaroo Island (35°54'02.3"S, 136°59'11.3"E), 20 Jul 2006, *Conran 2000 & Duggan* (AD, ADU); 24.5 km NE of Vivonne Bay on S Coast Hwy, Kangaroo Island (35°51'25.6"S, 137°25'04.7"E), 20 Jul 2006, *Conran 2003 & Duggan* (AD, ADU).

Drosera whittakeri Planch., *Ann. Sci. Nat. ser. 3* 9: 302 (1848)

Neotype here selected: South Australia: corner of Green Hill Road and Cemetery Road, Encounter Bay (35°32'25"S 138°36'23"E), *A. Lowrie 2835* & *D.E. Murfet*, 8 Sept 2003 (*neo*: AD, *isoneo*: PERTH, MEL, K, HL).

Illustrations: Lowrie (1998: 261); Lowrie (1998: 263, photos).

Perennial *herb*, solitary, tuberous, green, orange-yellow or red, with leafy rosette, 4–8 cm diam. *Tuber* orange, ± globose, *c.* 6–10 mm long, c. 6–10 mm diam., depressed laterally, enclosed in a number of black papery sheaths at the end of a vertical subterranean stem 4–5 cm long. *Leaves* broadly spathulate, adpressed to the soil surface, with 6–15 leaves per rosette; petiole 15–35 mm long, 4.5–5.5 mm wide at base, dilated to 6.0–7.5 mm wide distally at base of lamina, longitudinally strongly 5-ridged, margin entire, glabrous; *lamina* obovate to broadly obovate, 10–15 mm long, 9–13 mm wide at anthesis, basal margin entire, distally dentate with apex dentate (more readily observed from abaxial surface), with glandular trichomes terminating each apical dentate marginal segment, insect-catching glands positioned on adaxial surface near margin of lamina with slightly shorter glands medially, trichomes green to translucent red with dark red glandular heads, abaxial lamina glabrous, veins branched towards apex (more readily observed in dried, blackened specimens). *Inflorescence* consisting of single flowers arising from the centre of the rosette, or sometimes terminal on a short (<10 mm) scape. *Flowers* up to 20, pedicels ± similar in colour to leaves, 3–6 cm long, sparsely covered with scattered sessile glands, pedicels ± decumbent in fruit, prostrate or slightly arching. *Sepals* green to reddish, narrowly ovate-elliptic, 6–8 mm long, 3–4 mm wide, margins and apex entire, abaxial surface black dotted (more easily observed in dried specimens), with a small number of scattered minute sessile glands similar to those on scape, otherwise glabrous. *Petals* white, cuneate, margins entire, apex truncate-crenulate, 8–15 mm long, 6–10 mm wide. *Stamens* 5, 4–5 mm long, filaments white, anthers white, pollen pale yellow. *Ovary* green, obovoid, 2–2.3 mm long, 1.7–1.9 mm diam. *Style-stigmas* 3, white, 1.5–1.7 mm long, each divided into many filiform branching segments, glabrous, stigmatic portion white, dividing apically into 4, flat-topped, papillose segments. *Seed* charcoal black, angular, ovoid-cylindrical, 1–1.3 mm long, 0.7–1 mm diam., micropyle within indented basal pole, apical pole indented, surface sculpture irregularly hexagonal with weakly thickened anticlinal margins. (Figs 2d; 3h,i). *Chromosome number 2n* = 28 (Kondo & Lavarack 1984).

Typification: Planchon (1848) cited two specimens in his treatment of *Drosera whittakeri*: "In Novae-Hollandiae ora meridionali ad Port-Phillips; Gunn no. 6 in herb. Hook. et ad Encounter-bay; Whittaker ibid." This collection was purchased by W.J. Hooker and is now housed at K (although apparently without the *D. whittakeri* and *D. aberrans* specimens). Because that citation includes elements from two species as defined here, *D. whittakeri* s. str. should be considered to be typified by the Whittaker collection "ad Encounter-bay; Whittaker ibid [in herb. Hook.]", as it represents material from South Australia within the range of *D. whittakeri*, whereas the specimen "In Novae-Hollandiae ora meridionali ad Port-Phillips; Gunn no. 6 in herb. Hook." is excluded as it represents material from Port Phillip Bay in Victoria, where only *D. aberrans* occurs. However, searches at K and BM have failed to locate any Whittaker or Gunn collections of *D. whittakeri* or related species. Because there are no collections referable to the original description, nor apparently any by either of those collectors from South Australia of this species, a neotype (*Lowrie 2835* & *Murfet*) has been designated from recent collections taken near Encounter Bay, near where Whittaker's original collections were made and where the species is still locally abundant.

Etymology: the epithet *whittakeri* honours Joseph Whittaker (1815–1894), a nurseryman from Breadsall, Derbyshire, England who collected c. 300 plant specimens from Adelaide and the southern Mount Lofty Ranges to Encounter Bay, South Australia from 1839–1840.

Habitat: common in a range of soil types from sand to clay-loams, rarely lateritic gravels, but not on limestone-derived clays. The plants grow in full sun or partial shade in open woodlands, heaths and grasslands.

Distribution: widespread through the Mount Lofty Ranges, South Australia as well as Kangaroo Island, with scattered collections from Yorke Peninsula (Fig. 1d). The species extends east in the Murrayland to the Coorong National Park and Monarto Conservation Park, where its range overlaps narrowly with *D. aberrans*, but with no obvious intermediates.

Conservation status: common and well represented in conservation areas. Not threatened.

Notes: the species flowers July–October and has a dry dormancy period as a subterranean tuber over summer. Leaf colour does not appear to be a function of exposure, as green-, orange-yellow- and red-leaved forms grow together at many sites, and continue to do so under uniform cultivation (Clayton 2003 and pers. obs. by both authors), although plants also tend to turn redder with age.

A larger, more-robust form of *D. whittakeri* has also been reported from the Adelaide Hills (Lowrie 1989, 1998; Clayton 2003) and often has many more flowers and semi-pendulous rather than prostrate fruits. Nevertheless, examination of populations across the species'range shows that there is gradual introgression between the forms, with no clear morphological or geographic boundaries. The robust plants often grow on relatively better soils (loams versus sands), often in association with *Acacia paradoxa*

DC. (Mimosacaeae), and their size might reflect increased soil nitrogen under these shrubs. However, since they continue to grow larger than the type (coastal backdune) form in cultivation, they might best be considered an ecotype.

Selected specimens examined: South Australia: Mount Billy Conservation Park, Hindmarsh Tiers (35°25'27"S 138°34'12"E), *Lowrie 2802* & *Murfet*, 5 Sept 2003 (AD, PERTH, MEL); Talisker Conservation Park (35°37'11"S 138°09'15"E), *Lowrie 2831 & Murfet*, 8 Sept 2003 (AD, PERTH, MEL); Beach-side heathland, Parsons Beach, Encounter Bay (35°37'59"S 138°28'45"E), *Lowrie 2834* & *Murfet*, 8 Sept 2003 (AD, PERTH, MEL); Corner of Green Hill Road & Cemetery Road, Encounter Bay (35°32'25"S 138°36'23"E), *Lowrie 2835 & Murfet*, 8 Sept 2003 (AD, PERTH, MEL); Piggot Range Road, Southern Mount Lofty Ranges (35°08'09.2"S 138°35'13.1"E), *Conran 1972*, 5 Jul 2006 (AD, ADU); Green Hill Road 350m N of road to Encounter Bay (35°32'05.3"S 138°36'09"E), *Conran 1977*, 5 Jul 2006 (AD, ADU); Playford Hwy, 22.5 km SW of Kingscote, Kangaroo Island (35°46'21.4"S, 137°37'34.2"E), 20 Jul 2006, *Conran 1992 & Duggan* (AD, ADU); 29 km W of Parndana on Playford Hwy opposite Flinders Chase National Park, Kangaroo Island (35°47'32.6"S, 136°55'38.9"E), 20 Jul 2006, *Conran 1996 & Duggan* (AD, ADU); 2.5 km W of Gosse Richie Road turnoff, 27.5 km W of Parndana, Kangaroo Island (35°47'49.3"S, 136°57'04.3"E), 20 Jul 2006, *Conran 1997 & Duggan* (AD, ADU); 4km S of Playford Hwy on Gosse Richie Road, Kangaroo Island (35°49'39.2"S, 136°58'44.0"E), 20 Jul 2006, *Conran 1999 & Duggan* (AD, ADU); c. 9.5 km N of S Coast Hwy along Gosse Richie Road, Kangaroo Island (35°54'02.3"S, 136°59'11.3"E), 20 Jul 2006, *Conran 2001 & Duggan* (AD, ADU); 21 km E of Gosse Richie Road turnoff along S Coast Hwy (35°39'02.4"S, 137°07'38.4"E), 20 Jul 2006, *Conran 2002 & Duggan* (AD, ADU); 5 miles [8 km] W Murray Bridge (35°7'S 139°11'E), *Filson 3027*, 4 Aug 1960 (MEL37462A); Belair National Park ca 7 miles [11.2 km] SSE Adelaide (35°0'S 138°37'E), *Filson 1658*, 7 Sep 1958 (MEL37625A); Kalkaburg 15 miles [24 km] NW from Ardrossan (34°16'S 137°44'E), *Tepper 761*, Jan 1880 (MEL96940A); Near Mount Lofty (34°58'S 138°43'E), *Tepper s.n.*, 1884 (MEL96943A); Yorke Peninsula, *Tepper s.n.*, no date (MEL96948A); North Cunningham (34°25'S 137°48'E), *Tepper 943*, no date (MEL96950A); Georgetown 33°22'S 138°24'E), *Richards s.n.*, 1893 (MEL96956A); Newland Head Conservation Park (35°38'S 138°31'E), *Murfet 1081b*, 4 Aug 1991 (MEL715861A).

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Romnalda ophiopogonoides (Asparagales: Laxmanniaceae), a new and endangered species from the Wet Tropics bioregion of north-east Queensland

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Abstract

Romnalda ophiopogonoides Conran, P.I.Forst. et Donnon *sp. nov.* from the Cape Tribulation -Daintree area in the Wet Tropics bioregion of north-east Queensland is described, illustrated and compared with related species. A conservation status of Endangered is proposed. Notes on habitat, distribution and cytology and a key to the species of *Romnalda* are provided.

Introduction

The genus *Romnalda* P.F.Stevens (Asparagales: Laxmanniaceae) was erected to accommodate three species of erect-stemmed, strap-leaved, generally stilt-rooted rainforest monocots from northern Australia and New Guinea. Although superficially similar to *Lomandra* R.Br., especially the tropical *L. banksii* (R.Br.) Ewart, it differs in several features, not least of which is that *Romnalda* is always hermaphrodite, whereas all species of *Lomandra* are dioecious (Stevens 1978), or only rarely and sporadically bear a few hermaphrodite flowers on otherwise unisexual inflorescences (Briggs 1986). In this, *Romnalda* is much more like other Lomandroideae *sensu* Conran (1998) and in particular, superficially resembles the rare, strap-leaved, cauline understorey herb *Chamaexeros longicaulis* T.D.Macfarlane from moist tall open forests in far south-west Western Australia.

Romnalda papuana (Lauterb.) P.F.Stevens is known from five localities in lowland rainforest in Papua New Guinea (including New Britain) and the island of Pulau Yapen

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in Indonesian Papua (Stevens 1978). The species is rare, mostly unprotected and in need of conservation (Shapcott et al. 2006). Henderson (1986) recognised two species in Australia: *R. grallata* R.J.F.Hend. from several populations in two high altitude (>600 m) cloud forest regions in the Daintree area of the Wet Tropics bioregion of north-east Queensland, where it is currently listed as Rare under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (*EPBC 1999*) (DEH 2006), although it has been de-listed in Queensland. A second species, *R. strobilacea* R.J.F.Hend. & P.R.Sharpe, is known from a small number of rainforest pockets on basaltic soils in south-east Queensland (Logan River Branch SGAP (Queensland Region) Inc. 2005) and is listed as Vulnerable under both Federal (*EPBC 1999*) and State (*Nature Conservation Act 1992*) legislation.

Since Henderson's (1986) treatment, another taxon with restricted distribution has been discovered in the Cape Tribulation – Daintree area (specifically in the region of Cooper Creek) in the Wet Tropics bioregion. This taxon has been known under the HISPID code names of *Romnalda* sp. (Roaring Meg P.I.Forster+ PIF4402) (Forster 1994) or *R.* sp. (Cooper Creek P.I.Forster+ PIF4402) (Forster 1997, 2002, Wang 2007). Although bearing some similarities to *R. grallata*, the taxon differs in a range of features and largely occupies a different niche of the Wet Tropics bioregion, although there are some places where the two are sympatric.

Population genetic studies of *Romnalda* (Shapcott et al. 2006) showed clearly that the Cooper Creek plants were distinct from *R. grallata*, although occasional hybridisation occurs when the two species are sympatric. The new taxon, described below as *Romnalda ophiopogonoides*, is regarded as Endangered (Shapcott et al. 2006), although it has yet to be officially listed as such. It is given this status because there are only about 500 plants at the three known localities. many of which are in areas of private land adjacent to National Parks, or along walking tracks where they may be subject to tramping effects.

Methods

Herbarium specimens of *R. ophiopogonoides* and other *Romnalda* species lodged at BRI and AD were examined for as many populations as possible using Scanning Electron Microscopy (SEM) and a stereo dissecting microscope, as were living specimens of these species growing at ADU. Morphological descriptions were based on fresh, dried and spirit material. All three species of Australian *Romnalda* have been examined in the field and vouchered by the second author.

Leaf anatomy studies used dried material for consistency, with the samples rehydrated in warm water. Transverse sections were cut with a sliding microtome at 10–15 µm, stained with 1% aqueous Toluidine Blue and mounted in CrystalMount®. Cuticles were prepared following the methods of Christophel and Lys (1986), stained in 0.5% aqueous Crystal Violet, mounted in CrystalMount® and examined using Nomarski Differential Interference Contrast microscopy. The cuticles were compared using a modified version of the cuticular character set for *Cordyline* Comm. ex R.Br. (Conran 1997).

Chromosome counts were made from actively growing root tips excised from cultivated plants and pre-treated for 2 hours in 250 ppm 8-hydroxyquinoline, as well as meiotic counts from buds where available. Fixation used Bradley's fixative (4:3:1 chloroform: ethanol: glacial acetic acid) for at least 24 hours followed by storage in 70% ethanol at -20°C. Root tips were hydrolysed for 20 minutes in 5N HCl at 20°C, and rinsed in distilled water (2 × 10 mins). Anthers and root tips were stained for 20 min and squashed in a drop of Carbol Fuchsin (Prakash 2000). Coverslips were removed by the freeze method of Conger & Fairchild (1953) using a -80°C freezer, the slides air-dried and specimens mounted in Gurr's Euparal®. Chromosome spreads were counted and photographed under oil-immersion.

Results and Discussion

Morphology

Comparison of *R. ophiopogonoides* with the other members of the genus shows that it differs in a range of morphological features (Table 1). The stems are shorter than the other Australian taxa and the leaves are smaller and generally with fewer teeth, and unlike *R. grallata*, are concolorous. In addition *R. grallata* lacks the persistent bracts of *R. ophiopogonoides.* The new species is very unlike *R. strobilacea* in inflorescence size and flower cluster position. The flowers are similar in size to *R. papuana*, but the stamens of *R. ophiopogonoides* differ in their combination of filament and anther size and shape characteristics from the rest of the genus. Similarly, the ovary and style are smaller than in *R. papuana.* The fruit seems to be intermediate in size between *R. grallata* and the other species although this is based on data from the single known, not quite mature, capsule.

Anatomy

Investigation of the epidermal anatomy of the three Australian species of *Romnalda* (Fig. 1) showed that they differed both in mean cell size as well as aspects of cuticular sculpturing (Table 2). In general, the cells in *R. ophiopogonoides* were larger on both surfaces than in the other two taxa, but the stomata were intermediate in size and the subsidiary cells closer in size to *R. grallata.* The cuticles of *R. ophiopogonoides* were unsculptured, again resembling *R. grallata.*

Internal leaf anatomy for the Australian species (Fig. 2) showed that there were differences in thickness and fibre distribution (Table 2). The leaves of *R. ophiopogonoides* were thinner than the other two, and although resembling *R. grallata* in lacking hypodermal fibres and possessing fibre bundle extensions and leaf marginal fibre masses, the new species differed from both *R. grallata* and *R. strobilacea* in the rarity of fibres scattered in the chlorenchymatous outer mesophyll.

Cytology

The chromosome number for the new species is $2n = 16$ (Fig. 3), the same as that reported for *R. grallata* by Henderson (1986).

Biogeography and Ecology

The genus was regarded by van Steenis (1985) as an Australian element that had expanded to Malesia. Within New Guinea, the isolated Vogelkop and island disjunctions follow a recurring pattern seen in other organisms with low dispersal ability and/or specific habitat needs such as birds of paradise, invertebrates and numerous plants (Heads 2001). This pattern is thought to have arisen as the Australian plate moved northwards, accreting land masses to the north as it went.

Table 1. Morphological comparison of *Romnalda* spp.

Character	***R. grallata***	***R. ophiopogonoides***	***R. papuana****	***R. strobilacea***
Max. stem length (cm)	40	6	5	10
Leaf length × width (mm)	120–350 × 7–16	60–120 × 3–5	220–380 × 4–5	500–800 × 8–13
Leaf apical teeth	4–8	3–4 (rarely 5)	5–12	absent (rarely 1–3)
Leaf surfaces	discolorous	concolorous	concolorous	inconspicuously discolorous
Inflorescence length (cm)	9–30	8–20	≤20	60–90
Flower clusters	axillary and along branches	axillary and along branches	axillary, branches and branch apices	branch apices
Bract persistence	withering early	persistent	persistent	persistent
Sepal shape	ovate-deltoid	deltoid	ovate	elliptic
Sepal length × width (mm)	3.5–4.0 × 1.1–1.4	3.0–3.5 × 1.0–1.2	3.0–3.5 × 1.0–1.2	2.8–3.2 × 0.8–1.1
Petal shape	elliptic-oblong	ovate-elliptic	elliptic	obovate-obcordate
Petal length x width (mm)	4.0–4.5 × 1.2–1.5	3.5–4.0 × 1.1–1.4	3.5–3.8 × 0.7–0.8	2.3–2.7 × 0.6–0.8
Filament shape	linear	narrow triangular towards base	narrow triangular towards base	triangular towards base
Filament length outer; inner; anther (mm)	c. 2.0; 2.5; 1.0	c. 2.0; 2.0; 0.6	c. 2.2; 2.5; 1.0	c. 1.0; 0.6; 0.6
Ovary length (mm)	c. 1.5	c. 0.75	c. 1.5	c. 1.0
Style shape	apically geniculate	straight to curved apically	straight	curved
Style length (mm)	3.25–3.75	1.75–2.25	0.8–1.2	0.75–1.0
Fruit shape	ovoid, short-beaked	hemispherical, long-beaked	ovoid, short-beaked	depressed globular, apiculate
Fruit length × width (mm)	c. 10 × 10	c. 8 × 5.5	4–5 × 3–4	4.5–6 × 4.5–6
Chromosome number	n = 8; 2n = 16	n = 8; 2n = 16	not known	2n = 16

* data mostly from Stevens (1978).

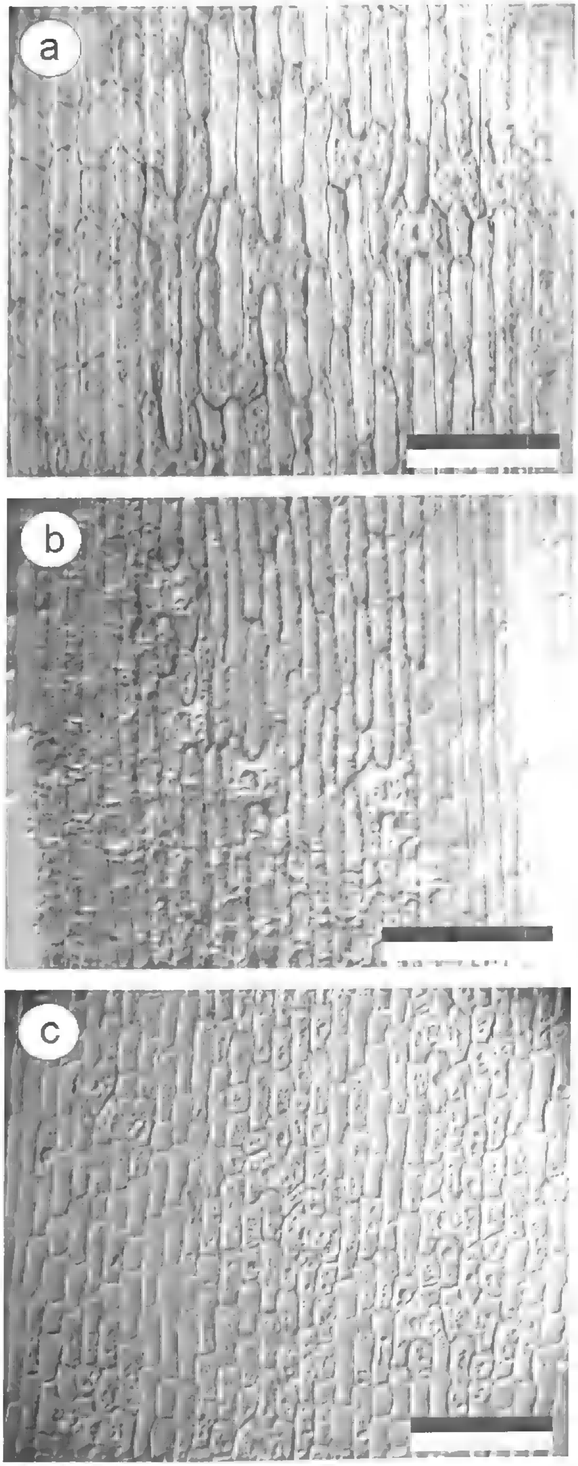

Fig. 1. *Romnalda* leaf abaxial epidermal anatomy. **a,** *R. grallata*, from *Conran 2299* (ADU); **b,** *R. ophiopogonoides*, from *Sankowsky 2717* (BRI, ADU); **c,** *R. strobilacea*, from *Conran 2300* (ADU). Scale bars = 50 µm.

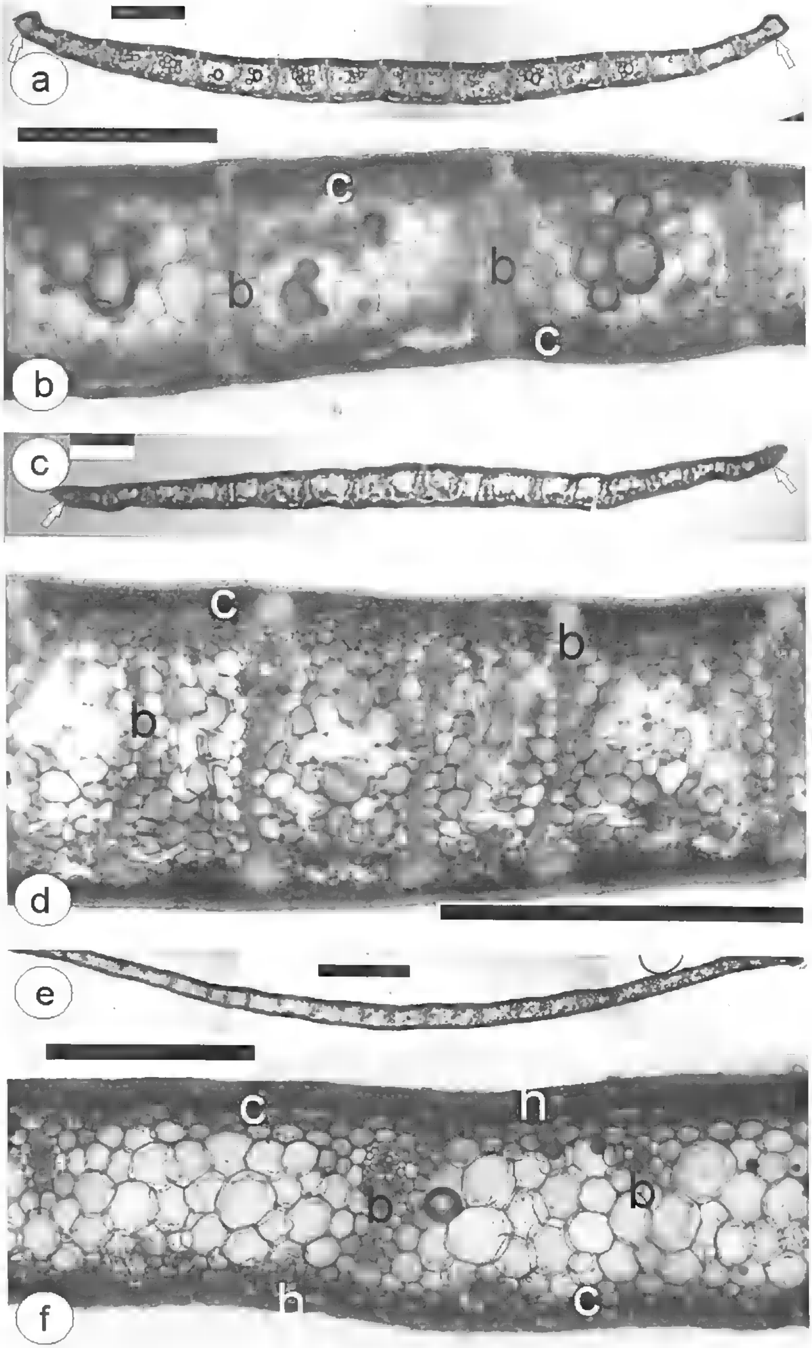

Fig. 2. *Romnalda* leaf internal anatomy. **a, c, e,** lamina in transverse section; **b, d, f,** detail of vascular bundles and associated tissues. **a–b,** *R. grallata*, from *Conran 2299* (ADU); **c–d,** *R. ophiopogonoides*, from *Sankowsky 2717* (BRI, ADU); **e–f,** *R. strobilacea*, from *Conran 2300* (ADU). **b** = fibres associated with vascular bundles, **c** = fibres associated with chlorenchyma, **h** = hypodermal fibres, arrows indicate marginal fibre bundles. Scale bars **a, c, e,** = 1 mm; **b, d, f,** = 250 µm.

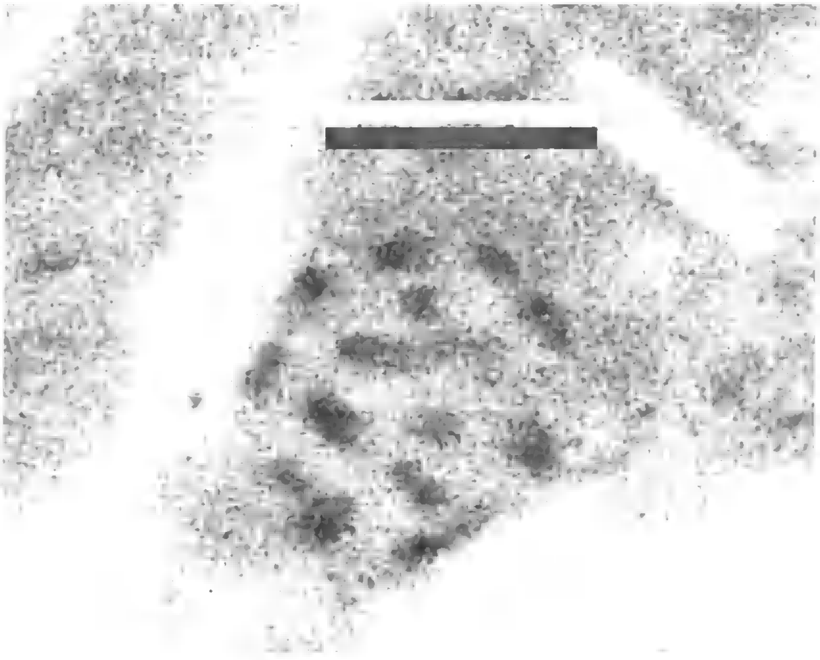

Fig. 3. *Romnalda ophiopogonoides* chromosomes, voucher from *Sankowsky 2717* (BRI, ADU). Scale bar = 5 µm.

The similarly narrow and disjunct population patterns in Australia suggest that *Romnalda* is restricted through its apparently low dispersal ability and relatively specific habitat requirements. Plants of the Australian species show no specific adaptations for dispersal and the seeds are unprotected and short lived (JGC unpubl. obs.). There is some evidence that the plants can disperse locally along waterways by fragmentation of the colonies during the wet season (G. Sankowsky, pers. comm.), but this is a 'downhill only' option and not likely to lead to long distance dispersal.

Taxonomy

Romnalda ophiopogonoides Conran, P.I.Forst. et Donnon, ***sp. nov.*** **Fig. 4**

Affinis *R. grallatae*. Herba caespitosa; radices gralliformes. Folia numerosa, 6–12 cm longa, minute 3(–4) -dentata. Flores fasciculati in ramulis et axillis portati; bracteae numerosae, persistentes. Petala longiora sepalis; stylus ovario minimum duplo longior.

Holotype. Queensland: Cook District: Mount Sorrow track before razorback, Daintree National Park, 2.5 km W of Cape Tribulation, *P.I. Forster PIF21988, R. Booth, R. Jago & R. Jensen*, 2 Dec 1997 (BRI [1 sheet + spirit]). (*Iso*: MEL, QRS).

Plants 10–15 cm tall, tufted to clump forming. Stems to c. 6 cm long, branching, erect with wiry, stilt-like adventitious supporting roots. Leaves numerous, 6–12 cm long, 3–5 mm wide, concolorous, obtuse to truncate with 3–4 (rarely 5) minute apical teeth. Inflorescence 8–20 cm long, simple or few-branched; peduncle dark purplish green;

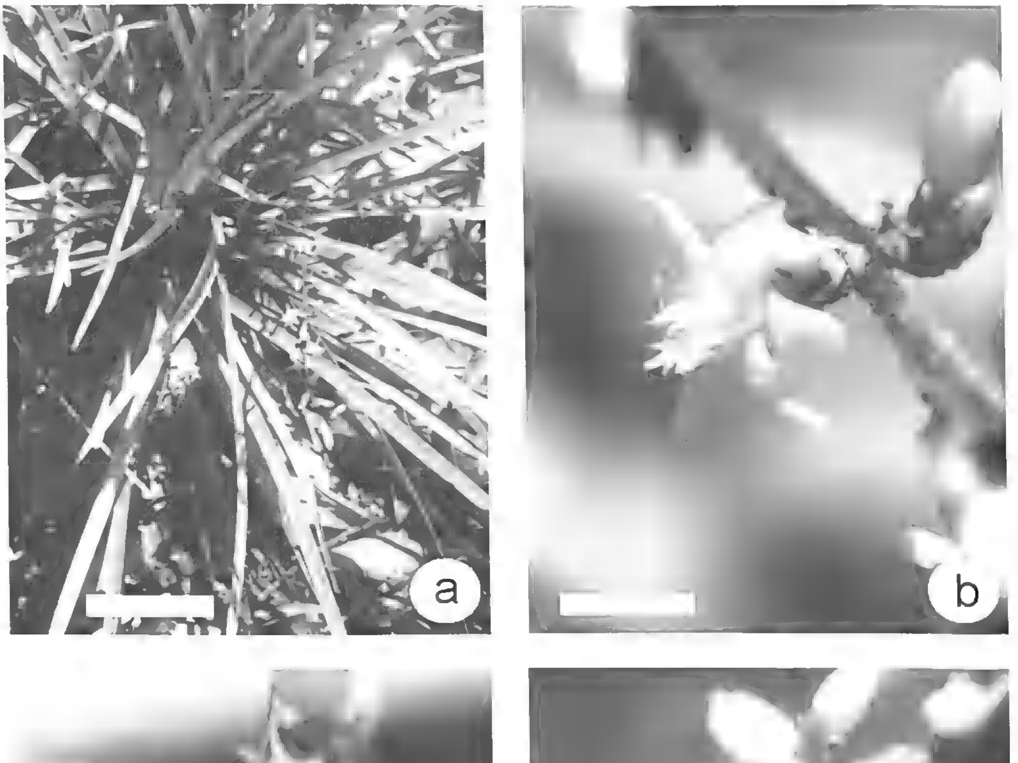

Fig. 4. *Romnalda ophiopogonoides* Conran, P.I.Forst et Donnon. **a**, plant; **b**, flower and buds, lateral view showing persistent bracts **c**, flower, front view showing straight style and conspicuous scattered wax crystals on the peduncle; **d**, developing fruit showing asymmetrical development and stylar beak, from *Conran 2298* (ADU). Scale bars **a**, = 20 mm, **b–d**, = 2 mm.

flowers clustered in branch axils and along branches. Flowers white, each subtended by a small, brownish purple persistent bract. Outer perianth whorl of 3 sepals deltoid, 3.0–3.5 mm long and 1–1.2 mm wide, abaxial apex purple. Inner perianth whorl of 3 petals ovate-elliptic, 3.5–4 mm long and 1.1–1.4 mm wide. Stamen filaments basally narrow-triangular, pale cream, outer 3 to 2.0 mm long, fused basally to sepals for 0.25 mm, inner 3 to 2.0 mm long, fused basally to petals for 0.75 mm; anthers c. 0.6 mm long. Ovary c. 0.75 mm long; style 1.75–2.25 mm long, straight or curved apically, tapering, stigma minute. Capsule hemispherical, 7–9 mm long, 5–6 mm wide, somewhat flattened and tapering into a long, persistent stylar beak abaxially (at least in immature fruit). Seed not seen. Chromosome number $n = 8$, $2n = 16$ (Fig. 3, voucher *Sankowsky 2717*).

Etymology: the specific epithet is derived from the generic name *Ophiopogon* (Greek for snake's beard) and the Greek suffix *-oides* (meaning 'to resemble'); in reference to the resemblance of this species to the widely cultivated *Ophiopogon japonicus* (Thunb.) Ker Gawl. (Mondo Grass).

Habitat: the new species grows in generally low altitude (<800 m) rainforests (complex mesophyll to notophyll vineforests; Webb 1959) on substrates derived from granites or metamorphics. It occurs as a forest floor herb in extremely low light, high moisture and high humidity environments. These habitats are characterised by high species endemism and diversity, indicating long term environmental stability, apart from occasional devastation by cyclones (Tracey 1981, Crisp et al. 2001).

Distribution: currently only known at four localities in the Cape Tribulation area (Fig. 5) along the upper Cooper Creek, Roaring Meg Creek, and near Mt Sorrow in Daintree NP.

Conservation status: this species has a limited distribution, small total population size (c. 500 plants) and many of the known plants are exposed, e.g. growing along walking tracks or in unprotected areas subject to human impact and/or development. Moreover, given the mutual potential genetic contamination in areas where the species is sympatric with the equally rare *R. grallata*, conservation of both taxa becomes an issue. There is some overlap in flowering times between them, and both species and their hybrids appear to be self-compatible and capable of introgression (Shapcott 2006). *Romnalda ophiopogonoides* can be categorised as Endangered on the basis of the criteria A4c,e; B2(i-v),D2 (IUCN 2001).

Specimens examined: Queensland: Cook District: Roaring Meg Creek just below junction with Alexandra Creek, *L.J. Webb 11667 & J.G. Tracey*, Jun 1973 (BRI); Roaring Meg Creek near Mt Pieter Botte, Daintree National Park, *A. Shapcott RGC7*, 5 Nov 2003 (BRI); Track to Mt Sorrow razorback, Daintree National Park, *A. Shapcott RGC6*, 3 Jun 2003 (BRI); End of Turpentine Road, Little Cooper Creek, *A. Shapcott RGC4*, 2 Jun 2003 (BRI); Headwaters of Cooper Creek, 3.5 km W of Thornton Beach, *P.I. Forster PIF4402 & M.C. Tucker*, 17 Jun 1988 (BRI, CANB); Turpentine road, Cooper Creek, *L.W. Jessup GJD2814 & al.*, 26 Nov 1989 (BRI); Near Cooper Creek, *G. Sankowsky 655 & N. Sankowsky*, 13 Sep 1987 (BRI); Near Cooper Creek, *G. Sankowsky 2717*, Dec 2006 (BRI, ADU).

Notes: flowering occurs over an extended period, but mainly from June to November. In cultivation, plants flower more or less continuously across the year , with buds, flowers and fruits all carried at the same time (Conran pers. obs.) but fruit are almost unknown in the field (G. Sankowsky pers. comm.). Flowering in *Romnalda ophiopogonoides* also follows an altitudinal gradient, with the latest flowering populations occurring at higher, cooler altitudes (Shapcott et al. 2006).

Romnalda ophiopogonoides is closest to *R. grallata* and then to *R. papuana*, although it is distinct genetically (Shapcott et al. 2006), morphologically (Table 1) and anatomically (Table 2). Genetically it differs mainly in allelic frequencies rather than unique alleles, but the degree of difference is comparable with that seen between the other species, supporting recognition at specific rank. Although there is some evidence of hybridisation with *R. grallata* when they are sympatric, they remain distinct at most localities. Flowering time seems to be climate-determined in *Romnalda* and altitudinal variation in flowering for *R. ophiopogonoides* seems to maintain genetic isolation of the populations, as well as maintaining reasonable levels of reproductive isolation from *R. grallata* (Shapcott et al. 2006).

Key to the species of *Romnalda*

1 Style shorter than ovary 2

1* Style at least twice as long as ovary 3

2 Plants less than 0.5 m tall; flower clusters along non-elongating branches, in axils and sub-terminal; leaves with 5–12 apical teeth .... ***R. papuana***

2* Plants over 0.5 m tall; flower clusters sub-terminal, floral axis elongating; leaves without apical teeth (or rarely 1–3) .... ***R. strobilacea***

3 Plants less than 15 cm tall; leaves mostly with 3 (rarely 4 or 5) apical teeth; style straight or apically curved; fruit flattened abaxially .... ***R. ophiopogonoides***

3* Plants more than 15 cm tall; leaves with 4–8 apical teeth; style apically geniculate; fruit globular .... ***R. grallata***

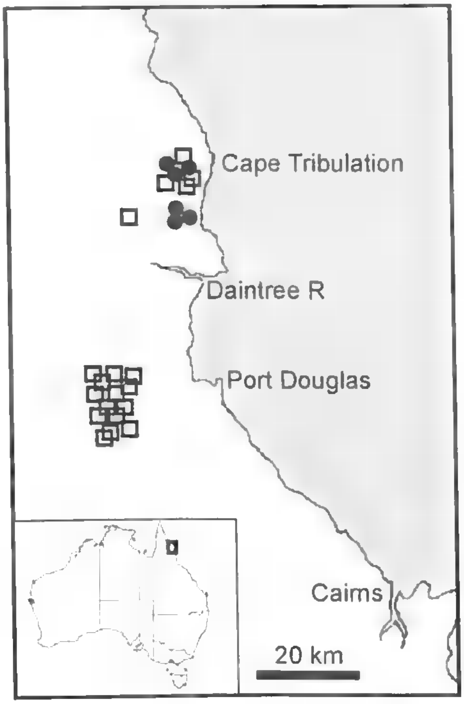

Fig. 5. Distribution of *Romnalda ophiopogonoides* (●) and *R. grallata* (□) in the Wet Tropics bioregion of north-east Queensland.

Acknowledgments

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Taxonomic interpretations of Australian native bamboos (Poaceae: Bambuseae) and their biogeographic implications

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Abstract

Australia's three native bamboo species – *Bambusa arnhemica*, *Mullerochloa moreheadiana* and *Neololeba atra* – are restricted to northern Australia. The most parsimonious explanation for the occurrence of bamboo in Australia is that there have been at least three founder events from Asia, but other possibilities exist including an Australian radiation involving *Neololeba* and *Mullerochloa*. *Bambusa arnhemica* may be allied to the Asian *B. blumeana* which occurs as close as Timor. I summarise historical evidence and biogeographic patterns for *B. arnhemica*, and describe the flowering wave phenomenon in the species, evidence which collectively suggests that *B. arnhemica* is neither very ancient nor very recent in origin. Current studies of the population genetics of *B. arnhemica*, and of the relationship between Australian and Asian bamboos, may yield fascinating further biogeographic insights.

Introduction

The tall, gracefully-arching leafy culms of bamboo are not characteristic of the Australian environment and, at a popular level at least, there is some resistance to the notion that any bamboo could be native to the continent. A negative view of bamboos has been reinforced by the invasiveness of several leptomorph (running) temperate-zone Asian species of *Phyllostachys* Siebold & Zucc. that are weeds in parts of south-eastern Australia (Lazarides 2002). Australia has three native bamboo species (Mallett & Orchard 2002) that, being confined to remoter tropical regions of the continent (Fig. 1), are not well known and have received almost no scientific attention until recently.

The three species are *Bambusa arnhemica* F.Muell., *Neololeba atra* (Lindl.) Widjaja, and *Mullerochloa moreheadiana* (F.M.Bailey) K.M.Wong (Table 1). *Bambusa arnhemica* is a robust, erect, clumping bamboo endemic to the higher rainfall north-west of the Northern

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Territory. It grows mainly in riparian forests and occasionally on rocky hillsides and other fire-sheltered non-riparian sites, ranging from Kakadu National Park west and south-west to the Daly River and north to Melville Island, often occurring in monodominant stands (Franklin & Bowman 2004). *Neololeba atra* is a slender, clumping, large-leaved species found in scattered locations in rainforest and vine-thicket along the Queensland coast from Mackay to the Torres Strait and also in New Guinea, the Moluccas, northern Sulawesi and the Philippines (Widjaja 1997). *Mullerochloa moreheadiana* is a rampant, non-twining scrambler endemic to the wet tropics of Queensland (Wong 2005), where it is known from the Innisfail and Daintree areas.

Cusack (1999) and Leu (2001) refer to *Schizostachyum* sp. 'Murray Island' as a fourth native species from the Torres Strait. However, this record is apparently not supported by herbarium specimens, its generic placement is speculative, and my enquiries suggest the relevant populations are likely to be remnants of disused plantations. On current evidence, these reports cannot be accepted as evidence that the species has established in the wild, let alone that it is a native species.

How did the three species reach Australia and how long have they been here? What is their relationship to Asian bamboos? Are *B. arnhemica* and *M. moreheadiana* truly endemic? Do they represent an Australian radiation, separate colonisation events from Asia, or Gondwanan remnants? These questions are necessarily grounded in taxonomic interpretation, and it is only in the past decade that the status of these species has been evaluated with sufficient care to allow the generation of plausible historical biogeographic hypotheses. In this paper,

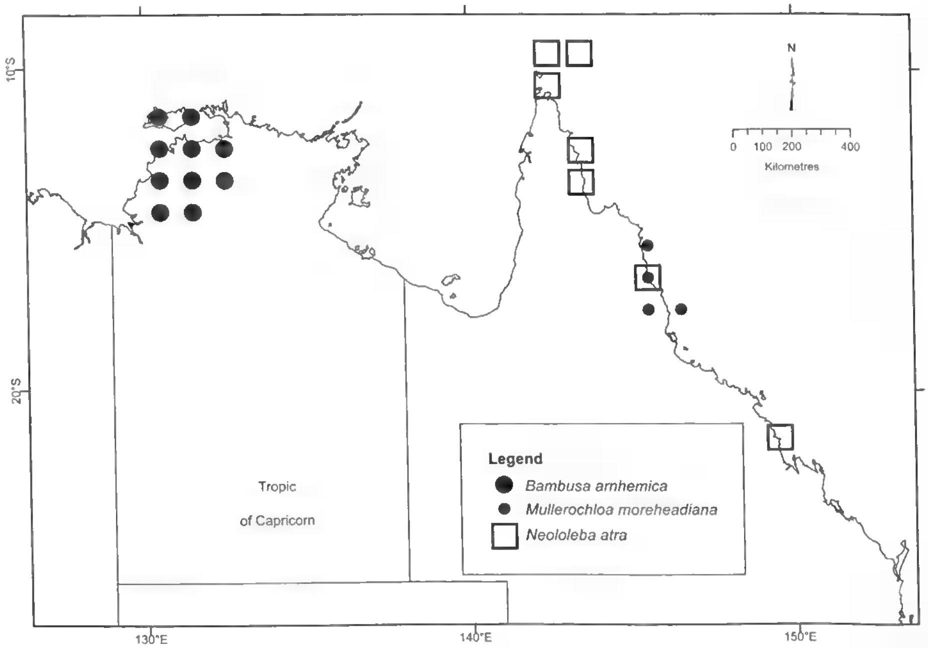

Fig. 1. Distribution of native bamboos in Australia. Data for *Bambusa arnhemica* are from the dataset underlying the distribution map in Franklin & Bowman (2004). Data for *Neololeba atra* and *Mullerochloa moreheadiana* are from CPBR (2007).

I will summarise current understandings about the taxonomic status and relationships of Australian native bamboos and briefly explore the emergent biogeographic implications.

Background: 'woody' bamboos

The 'woody' bamboos (Poaceae: Bambuseae) are a putatively monophyletic sister group to the herbaceous bamboos, tribe Olyreae, which together comprise the Bambusoideae (Zhang & Clark 2000, Grass Phylogeny Working Group 2001). The vernacular name 'bamboo' can generate confusion and reflects a chequered history of taxonomic interpretation (Clark 1997): in this paper, the term is taken to mean a member of the tribe Bambuseae.

The major centre of diversity is in Asia, especially southern China, with over 1,000 species in the Asia-Pacific region (Bystriakova et al. 2003). A second, lesser centre of diversity is in higher-rainfall tropical and temperate regions of Latin America with c. 430 species (Bystriakova et al. 2004). Five species occur naturally in continental Africa, 33 in Madagascar and three in the United States (Bystriakova et al. 2004, Triplett et al. 2006), along with three in Australia. No species occur naturally in Europe, although fossil bamboos have been found in Poland (Worobiec & Worobiec 2005).

Bamboos are obligately and fundamentally clonal. A feature of many species is a vegetative growth phase that may last decades or even centuries (Janzen 1976). Though at least a few species flower annually, many flower only at the end of this growth phase and either die, or their above-ground parts die, after flowering. Even more intriguing, many semelparous species flower and die synchronously and in spatio-temporal waves. The molecular mechanisms underlying the timing of these events remain "basic biological mysteries" (Judziewicz et al. 1999). A morphological corollary to this behaviour is the iterauctant inflorescence of some species, in which the pseudospikelets bear basal buds and are thus, theoretically, capable of indefinite proliferation. An ecological corollary of gregarious semelparity is a strong tendency for bamboos to occur in monodominant stands (Franklin & Bowman 2003, Griscom et al. 2007) or, in open forests, as monodominant understoreys (Saitoh et al. 2002, Taylor et al. 2004, Holz & Veblen 2006).

Probably no other large group of vascular plants is as poorly understood taxonomically as the Bambuseae. Natural selection appears to have favoured vegetative diversification. Key features such as rhizomes, culms, branch buds, branch complements and culm leaves do not fit well on standard herbarium specimen sheets and are not often collected. The flowers of many species are rarely available, and some species have been described without them. An Australian example is that the flowers of *M. moreheadiana* were first formally described by Clifford (1993), 104 years after the species was described. Furthermore, molecular techniques have yet to make substantial inroads into challenges at the generic and species levels.

The genus *Bambusa* Schreber, to which all three Australian bamboos were attributed until recently, appears to have been used as a repository for species of unknown affiliation. Ohrnberger (1999) recognized 139 species in *Bambusa* with a distribution centred in south Asia and extending north to Japan and south-east to the Solomon Islands and northern Australia, with an outlying species in Madagascar. The genus is demonstrably polyphyletic with at least some species of *Dendrocalamus* nested within it (Sun et al. 2005). Over recent decades, a considerable number of genera have been raised to accommodate obviously aberrant species or discrete groups (see brief reviews in Sun et al. 2005, Wong 2005). However, this process has proceeded in the absence of any clear definition of *Bambusa*, a problem at least partly addressed by Wong's (2005) "improving circumscription" of the genus. It remains unclear how many more nomenclatural changes are required to reduce *Bambusa* to coherent monophyly.

Taxonomic appraisals of Australian bamboos

After an early, chequered nomenclatural history (see Spencer 1986 for a brief summary), Queensland populations of the taxon now known as *Neololeba atra* were attributed to *Dendrocalamus forbesii*, a species described from New Guinea by Ridley (1886). Holttum (1967) transferred *D. forbesii* to *Bambusa* based on the rhachilla having distinct and equal internodes and lemmas of equal length. Whilst acknowledging its similarity to *Bambusa atra*, a species from New Guinea through to Sulawesi and the Philippines, Holttum considered them separable on the length of the lemma (8–10 mm in *B. atra*, 6–7 mm in *B. forbesii*). Widjaja (1997) argued that *B. forbesii* was indistinguishable from *B. atra*, reducing it to synonymy with the latter name taking precedence. At the same time, she described the new genus *Neololeba*, to which she transferred *B. atra* and described four new species from Indonesia. *Neololeba* can be distinguished from *Bambusa* by its simple branching system and a range of floral characteristics including pseudospikelet shape, the length of the rhachilla internodes, the absence of lodicules, and ovary shape. *Neololeba* also lacks the basal branches and robust, thick-walled culms of *Bambusa*.

Based on the original description by Mueller (1886), *B. arnhemica* has always been officially treated as an Australian endemic. Mueller's description was brief and although it does include a description of flowers – contrary to assertions by a number of subsequent authors including Ohrnberger (1999) – it was insufficient to ascertain the aptness of its placement in *Bambusa* nor to identify or exclude synonymy with Asian species. Mueller also raised the possibility that a second species occurred within the range of *B. arnhemica*. Franklin (2003a) found no evidence of a second species and concluded that, notwithstanding considerable discrepancies in the literature in the circumscription of *Bambusa*, *B. arnhemica* was a typical *Bambusa* based on pseudospikelet, floret and caryopsis features and the presence of thorns on the basal branches. The only possible discrepancy was that *Bambusa* species typically have lobed culm sheath auricles, but these are much reduced in *B. arnhemica* as they also are in *B. balcooa* Roxburgh (Stapleton 1994). Wong (2005) subsequently concurred with this judgement.

I also compared *B. arnhemica* with descriptions or illustrations of 14 other species of *Bambusa* known to have thorns (Franklin 2003a). Two of these, *B. bambos* (L.) A.Voss (syn. *B. arundinacea*) and *B. blumeana* J.H.Schultes are robust clumpers that are widely distributed (naturally and/or in cultivation) in Asia, with *B. blumeana* widespread in, and probably native to, Timor (Muller et al. 1998), 650 km north-west from the natural range of *B. arnhemica*. Most of the other species are of restricted distribution and many occur in China. *Bambusa arnhemica* appears to be closer to *B. blumeana* than *B. bambos* but can be distinguished from both on a number of vegetative and floral characteristics (Table 2). However, the smaller stature of *B. arnhemica* may be attributable to harsher growing conditions, and occasional clumps exceed 20 m in height and have culms to 13 cm in diameter (pers. obs.).

In providing the first description of the flowers of *Bambusa moreheadiana*, Clifford (1993) noted that its floral structures were consistent with the circumscription of *Bambusa* provided by Holttum (1967) with the exception of the number of anthers (Table 1). In contrast, Muller (2001) drew attention to a number of unusual vegetative traits of the species and

Table 1. Taxonomic history, distribution and key morphological features of the three Australian native bamboo species.

Morphological features selected for comparison of Australian species only.

	Bambusa arnhemica	***Neololeba atra***	***Mullerochloa moreheadiana***
Original description	Mueller (1886) as *B. arnhemica*	1. Ridley (1886) as *Dendrocalamus forbesii* 2. Lindley (1815) as *Bambusa atra* - never applied to Australian populations	F.M.Bailey (1889) as *Bambusa moreheadiana*
Source of current nomenclature	status quo confirmed by Franklin (2003a) and Wong (2005)	Widjaja (1997)	Wong (2005)
Other synonyms	-	*Bambusa forbesii* (Holttum 1967) also *Arundinaria cobonii, Gigantochloa novoguineensis*	-
Australian distribution	the north-west of the Northern Territory	Queensland: 1. Mackay; 2. Daintree; 3. Iron Range; 4. Torres Strait	Queensland wet tropics: populations in the Daintree and Innisfail regions
Non-Australian distribution	-	north to the Philippines	-
Habit	robust clumper to 20 m	clumping, to 12 m	scandent (non-twining); loosely clumping
Culms	robust; to 10(–12) cm diameter; internodes mostly < 40 cm long	thin-walled, < 4 cm diameter; internodes 30–80 cm long	< 4.5 cm diameter; internodes < 30 cm long
Branches	often >> 3 per node	1–3 per node	1 to many per node
Foliage leaves	< 20 cm long	> 30 cm long	mostly < 30 cm long
Pseudospikelets	to 45 (–70) mm long	< 20 mm long	5–10 mm long
Lodicules	3	absent	3
Anthers	6	6	4
Features	branches often present near culm base, thorny	slender, thin-walled culms with long internodes and no basal branches; large leaves	primary branches often reiterate culms, producing "culm sequences" to 60+ m long; branch buds in contact with the ground may develop rhizome-like structures

Table 2. A comparison of traits useful to distinguish *Bambusa arnhemica* from two widespread Asian thorny *Bambusa* species.

Data on *B. bambos* and *B. blumeana* are from Dransfield & Widjaja (1995) and from observations by the author of cultivated specimens.

Character	*B. arnhemica*	*B. bambos*	*B. blumeana*
Culm dimensions (length, diameter near base)	to 20 m x 10 cm	to 30 m x 15–18 cm	to 25 m x 20 cm
Position of primary branches on culm	absent below 0.5 m and usually from c. 2–8 m	at all nodes	at most nodes
Thorns	slender, confined to lower branches, not usually giving rise to leafy shoots	robust on lower branches, often giving rise to leafy shoots; small spines may be present on upper branches	robust, on lower and upper branches and often giving rise to leafy shoots
Culm leaf shape	varying little along culm		lower leaves shorter and narrower
Culm leaf hairs	glabrous or with pale hairs	glabrous or with brown hairs	hairs on back dark brown
Culm leaf blade (culm leaf)	narrowly triangular, erect	broadly triangular, more or less reflexed	lanceolate, erect at basal and upper nodes, horizontal to deflexed on mid culm
Culm leaf auricles	rudimentary or absent	forming a prominent wrinkled margin	short, with bristles to 15 mm long
Pseudospikelets	to 4.5 (–7) cm long	c. 2 cm long	to c. 5 cm long
Other features	upper and lower branches segregated and of contrasting form	leaves slightly glaucous below	

argued that it was quite unlike typical *Bambusa* species. Wong (2005) has since provided a thorough reappraisal of the taxon in tandem with a tighter circumscription of *Bambusa*, drawing attention to a range of vegetative and floral features that render it unique amongst bamboos. Noteworthy amongst these is the capacity of primary branches to reiterate culms, thus forming "culm sequences", and for branch buds in contact with the ground to develop rhizome-like structures. He placed it in the new, monotypic genus *Mullerochloa*, named in recognition of contribution of Len Muller, the north Queensland resident who recognised and drew attention to the uniqueness of the species. The affinities of *Mullerochloa* are unclear but may lie with *Soejatmia* K.M.Wong and *Neololeba* (Wong 2005).

Bambusa arnhemica - an historical and biogeographic case study

Endemicity may be interpreted as indicating that *B. arnhemica* has been in Australia for a long time. However, there are at least two plausible alternative hypotheses that could involve relatively recent arrival from Asia: *a.* that it is recently derived from *B. blumeana* in Timor or elsewhere; or *b.* that its parent population in Asia has since gone extinct. Historical and ecological perspectives provide context for considering these as yet unresolved alternatives.

The species was well-established in its current range before the arrival of Europeans, as the early European explorers found bamboo in abundance along many watercourses where *B. arnhemica* is known today (Table 3). The popular suggestion that Macassan trepangers introduced *B. arnhemica* to northern Australia from Sulawesi or nearby islands in the 18th or 19th centuries (White 1971) is not supported by the presence of live bamboo at Macassan camp sites or nearby springs (Macknight 1976, Bindon 1991, Mitchell 1995). In contrast, the introduced Tamarind tree *Tamarindus indica* L. is commonly associated with these situations. Furthermore, because trepang is most abundant in clear water, the major trepanging grounds in northern Australia were off rocky rather than mangrove-lined coasts. Thus it was that Macassan camp sites were concentrated from Cobourg Peninsula east to the Gulf of Carpentaria, and along the Kimberley coast in the west (Macknight 1973, 1976), a distribution that almost perfectly excises the coast adjacent to which *B. arnhemica* grows (Franklin & Bowman 2004).

Table 3. Some early European records of bamboo in the Northern Territory.

1839	John Lort Stokes	Darwin Harbour	Stokes (1846)
1845	Ludwig Leichhardt	South Alligator River	Leichhardt (1847)
1862	John McDouall Stuart	Mary and Adelaide Rivers	Stuart (1865)
1866	John McKinlay	Margaret, McKinlay, Mary Rivers and tributaries of the South Alligator River	McKinlay (1866)

A plausible but hypothetical case has been made that Aboriginal people could have reached Australia on bamboo rafts (Flood 1995, Bednarik et al. 1999). The Indigenous people of northern Australia made considerable use of *B. arnhemica*, principally as spear shafts but also for production of didgeridoos, long-stemmed smoking pipes, ceremonial frames, water carriers, wood-carving chisels and rafts (Tindale 1925, Bindon 1991, Marrfurra et al. 1995, Blake et al. 1998, G. Wightman pers. comm.). Bamboo was traded extensively east into Arnhem Land, and south and south-west from the Daly River area as far as the Kimberley (Thomson 1949, Berndt & Berndt 1988, G. Wightman pers. comm.). The Balamumu people from Caledon Bay on the east Arnhem coast, 420 km east of the distributional limit of *B. arnhemica*, specialised in the production of bamboo fighting spears (Tindale 1925). This evidence may be interpreted as suggesting long-standing cultural attachment to bamboo and thus a long period of co-existence. However, usage and cultural value need to be interpreted in the light of the demonstrable ability of Aboriginal people to rapidly adopt novel items into traditional diets and culture, as demonstrated by the fruit of the Tamarind *Tamarindus indica* (Mitchell 1995) and meat of Water Buffalo *Bubalis bubalis* (Bowman & Robinson 2002). Interestingly, I can find no record suggesting traditional Aboriginal use of either bamboo culm shoots or seed as food, a marked contrast with the "bamboo cultures" of Asia.

I have also been unable to identify any direct archaeological evidence from Aboriginal usage that *B. arnhemica* may have been in Australia for millennia. Remains of bamboo have been detected in archaeological deposits in Kakadu National Park, but only in deposits no more than, and possibly much less than c. 800 years of age (Clarke 1988). The lack of earlier records may reflect that bamboo does not last long in this situation (Annie Clarke pers. comm.). The persistence and detectability of bamboo residues on stone tools (Jahren et al. 1997) offers some prospect for further exploration of archaeological deposits. There is only one possible representation of bamboo in the extensive Arnhem Land Plateau rock art record (Chaloupka 1997, p189), a painting that is only a few hundred years old (P. Giuliani pers. comm.). It depicts a man playing a didgeridoo that is banded; the banding may be decorative or could represent bamboo nodes.

Thus, though the historic record provides no evidence of a human introduction of the *B. arnhemica* to Australia, it does not exclude the possibility. However, several strands of ecological evidence suggest that *B. arnhemica* has been in Australia for a considerable period of time. The first is its primarily riparian distribution, documented in detail by Franklin and Bowman (2004) and which should be interpreted in the absence of any obvious dispersal mechanism (Franklin 2003a) and a generation time of 40–50 years (Franklin 2004). The species occurs in six major and a number of minor adjacent catchments on the Australian mainland and a restricted series of minor catchments on Melville Island. Bathymetric maps indicate that these coalesced into two palaeodrainages during the last glaciation c. 20,000 years ago: the Daly River which flowed west and then north towards Timor, and the greater Adelaide River system which drained northwards between the current tip of Cobourg Peninsula and Melville Island towards Tanimbar Island (see Voris 2000 for relevant sea-level maps). Within these catchments, the species is widely dispersed and frequently abundant from minor tributaries to the edge of coastal floodplains, but missing from the upper parts of some catchments including most notably that of the Daly River. It is consistently absent from streams with shallow, poorly-drained profiles, and from rocky stream banks. Franklin and Bowman (2004) suggested these patterns reflect infrequent dispersal across catchment boundaries to random "starting points", followed by downstream dispersal.

Overlain on this distribution is a pattern of flowering patches that range from 0.002 to 3,200 km^2 (Franklin 2004). A "patch" is an area in which the majority (usually > 95%) of *B. arnhemica* clumps flowered simultaneously, i.e. typically for 4–6 months from the middle of the dry season to the early wet season, adjacent patches being distinguished by flowering in a different year, or by not flowering during the period 1996-2002 when the phenomenon was studied (Franklin 2004). The arrangement of patches bears only limited resemblance to catchments and some patches cut across catchment or sub-catchment boundaries as if superimposed arbitrarily. Both above- and below-ground parts of *B. arnhemica* die after flowering, regeneration occurring solely but often prolifically from seed with seedling densities of 1,000–2,000 m^{-2} being observed (Franklin 2004).

The patch structure of flowering in *B. arnhemica* corresponds to the flowering wave phenomenon reported in many bamboos (Janzen 1976) in which, after a long period of reproductive inactivity (about 30 years in *B. arnhemica*), a succession of patches flower in successive years. The opportunity to document the flowering wave in *B. arnhemica* across much of its range and at a variety of spatial scales, a study without parallel amongst bamboos, has facilitated the generation of an hypothesis for this perplexing phenomenon. Flowering in at least some bamboos occurs at fixed though long intervals (see Kawamura 1927 for an exceptional example). It is now generally agreed to be under the control of an endogenous mechanism (a biological clock) that operates largely independently of the physiological status of the plant and which is maintained across generations by intense selection against individuals that flower out of synchrony (Janzen 1976, Simmonds 1980, Franklin 2004). The challenge has been to relate such a mechanism to the wave phenomenon. I proposed (Franklin 2004) that a wave arises from a synchronously-flowering founder population when environmentally-triggered miscounts affect a neighbourhood of plants, causing most or all of them to flower earlier or later than others of the species but without altering the genetics underlying the biological clock. A succession of miscounts generates a temporally coherent wave. It follows that, since the wave is not generated by genetic processes, the patches remain fixed out of step and are thus reproductively isolated unless a subsequent miscount by chance brings them back into alignment. The resultant allochronic isolation may well have genetic consequences and even provide the basis for speciation. The drivers of miscounts, along with the molecular mechanisms associated with such a long-term biological clock, remain unknown, although some circumstantial evidence summarised by Franklin (2004) suggests that the clock may be sensitive to fluctuations in temperature.

Given that the flowering wave remains a temporally coherent event, it seems likely to have arisen through many small chance increments rather than a few large ones. It follows that the flowering wave in *B. arnhemica* must have taken many generations to arise. Furthermore, it appears to have been superimposed on an established distribution.

The time scales required for *B. arnhemica* to disperse across the landscape of the north-western Top End and to develop a complex flowering wave remain unclear. However, it is clear that many generations are required for this situation to have arisen, and at 40–50 years per generation, *B. arnhemica* arrived in Australia a long time before Europeans did. I suspect also that the species arrived long before the Aborigines c. 50,000 years ago, but this remains to be demonstrated. The question is under further investigation using molecular techniques.

Biogeographic hypotheses for Australian bamboos

One possible hypothesis for the origin of Australian bamboos – that they represent a local radiation following a single founder event from Asia – a naive hypothesis that might have been tempting when all three species were attributed to *Bambusa*, can be confidently ruled out. Two of the taxa are Australian representatives of Asian genera, and the third is an aberrant species of uncertain affinities.

On the current limited information, the most parsimonious biogeographic hypothesis for the occurrence of bamboos in Australia is that the three species are the products of at least three founder events from Asia (Franklin 2003b). The aptness of this perspective for *B. arnhemica* is particularly evident given its position within a prolific Asian genus. However, Wong (2005) has raised some plausible alternatives for *Mullerochloa* and *Neololeba atra* that warrant further consideration. There are two components to Wong's suggestions. The first is that *Mullerochloa* may be allied to, and derived from *Neololeba*, raising the possibility of a local radiation involving these two species. Given the aberrant nature of *Mullerochloa*, such an event may have occurred long in the past. This leads to the second component, the possibility that at least this bamboo lineage is of Gondwanan rather than Asian origin.

It is a biogeographic irony that the Bambuseae are thought to have originated in the lowland tropics of the Southern Hemisphere (Clark 1997) and yet are most prolific in Asia. Many elements of this story remain fragmentary and uncertain. Current efforts to shed light on the higher level taxonomy of the Bambuseae by the Bamboo Phylogeny Project (Iowa State University 2007), in which it is planned to include the Australian and related Asian species (K.M. Wong pers. comm.), are likely to have substantial and intriguing biogeographic implications. It is not implausible that Australia will prove to be at the centre of yet another biogeographic story to which it has long been regarded as peripheral.

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Geographic variation in *Crowea exalata* (Rutaceae) and the recognition of two new subspecies

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Abstract

Crowea exalata F.Muell. was sampled throughout its morphological and geographical range to test the validity of the current circumscription of the species and subspecies. Through numerical analysis of morphological and chemical (leaf flavonoids and volatile oils) data four taxa are recognised, subsp. *exalata*, subsp. *revoluta* Paul G.Wilson, subsp. ***magnifolia*** Gebert *subsp. nov.* and subsp. ***obcordata*** Gebert *subsp. nov.* Descriptions and a key to all taxa are provided.

Introduction

Crowea Sm. (Rutaceae) is an Australian genus of three species that was first described by J.E. Smith and named in honour of James Crowe esq. F.L.S. (Smith 1798, 1808). Smith, however, was not one to give specific epithets to species of monotypic genera, and in the case of *Crowea* this was done by Andrews (1800) when he described *C. saligna* Andrews (see Wilson 1970). Members of *Crowea* are multi-stemmed, erect, evergreen, woody perennials to 2 m tall with white to rose pink, solitary, axillary flowers.

Probably the closest relative to *Crowea* is *Eriostemon* Sm. (Bayly et al. 1998; Wilson 1998). *Eriostemon* contains two species, *E. australasius* Pers. and *E. banksii* A.Cunn. ex Endl. *Eriostemon australasius* is often found in sympatry with *C. saligna* and *C. exalata* F.Muell. from which it can be distinguished on the basis of floral morphology; *Crowea* has pilose anthers and pedicels 1–4 mm long, while *Eriostemon* has glabrous anthers and pedicels 4–12 mm long (Bayly et al. 1998).

In the past, the relationship between *Crowea* and *Eriostemon* has not been clearly

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defined. Mueller (1862) relegated *Crowea* to synonymy under *Eriostemon* and described *E. crowei* F.Muell. (based on *C. saligna*). Bentham (1863) did not accept Mueller's classification and recognised *Crowea* as a taxon distinct from *Eriostemon* and *Phebalium* with the species *exalata*, *saligna*, *angustifolia* and *dentata* (=*C. angustifolia*). Baillon (1873) placed both *Eriostemon* and *Phebalium* Vent. in *Crowea* as sections and coined the name *Eucrowea*, which included taxa now accepted as members of *Crowea*. Mueller's classification was followed by Moore and Betche (1893), Maiden and Betche (1916) and Beadle et al. (1962) who included the varieties *crowei* (= *C. saligna*) and *exalata* (F.Muell.) Maiden et Betche (= *C. exalata*) but most workers in the intervening period followed Bentham.

Crowea was last revised by Wilson (1997) who recognised three species, *C. saligna*, *C. angustifolia* and *C. exalata*. *Crowea saligna* is restricted to the Hawkesbury sandstone regions of Sydney, and *C. angustifolia* is restricted to the south-western corner of Western Australia (Wilson 1970). *Crowea exalata* has the largest geographical and ecological distribution of all the species in the genus being found from southern Queensland to central Victoria. It is found in coastal, inland and montane areas, on rocky, clayey or sandy, well drained, moist soils (Fig. 1).

Crowea exalata, as currently circumscribed, has two subspecies, *C. exalata* subsp. *exalata* and *C. exalata* subsp. *revoluta* Paul G.Wilson. These taxa are separated on leaf width and length, margin curvature and flower size, with subsp. *revoluta* being the morphologically smaller of the two subspecies (Wilson 1997, Duretto 1999).

The use of chemical characters is now well established in many areas of systematics, including taxonomy (McClure & Alston 1966, Conn & Whiffin 1987, Southwell & Brophy 1992, Raleigh et al. 1994, Duewell 1997, Bayly et al. 1998), studies of geographic variation (Banks & Hillis 1969, Brooker & Lassak 1981, Whiffin & Ladiges 1992, Middleton et al. 1996, Wright & Ladiges 1997), hybridisation (Whiffin 1977, 1981; Leach & Whiffin 1978) and introgression (Flake et al. 1978). In systematic studies, volatile oils have proved useful in the area of infraspecific variation and species relationships, whereas phenolics, such as flavonoids, usually prove more useful at the species or genus level (Harborne & Turner 1984).

The use of volatile oils in taxonomy has a major advantage in that they provide large numbers of characters with no bias, are fairly accurate and are quantifiable (Whiffin 1977, 1982b; Whiffin & Hyland 1989; Whiffin & Ladiges 1992). Volatile oils have also been shown to be under strict genetic control (Hanover 1966, von Rudloff 1972). Even though environmental factors are known to affect the quantity of oil produced, the composition of the oil, expressed as the percentage of the total oil accounted for by each compound, does not seem to vary significantly on a seasonal basis (von Rudloff 1972; Whiffin 1982a, 1982b; Leach & Whiffin 1989). Ontogenetic variation is known to affect the composition of the oil, with a significant difference between young and mature leaves (von Rudloff 1972, Whiffin 1982b, Whiffin & Hyland 1989, Leach & Whiffin 1989). For analytical purposes, variation due to ontogenetic and environmental factors can be eliminated or reduced by utilising mature leaves only (Whiffin 1982b, Whiffin & Hyland 1989, Leach & Whiffin 1989).

The chemistry of *Crowea* has received little attention in the past. The essential oils from *C. saligna* were first described by Penfold and Morrison (1922, cited as *E. crowei*), while more recently a study of the major essential oil compounds of *Crowea* taxa has been published (Brophy et al. 1997). Brophy et al. (1997) described five chemotypes,

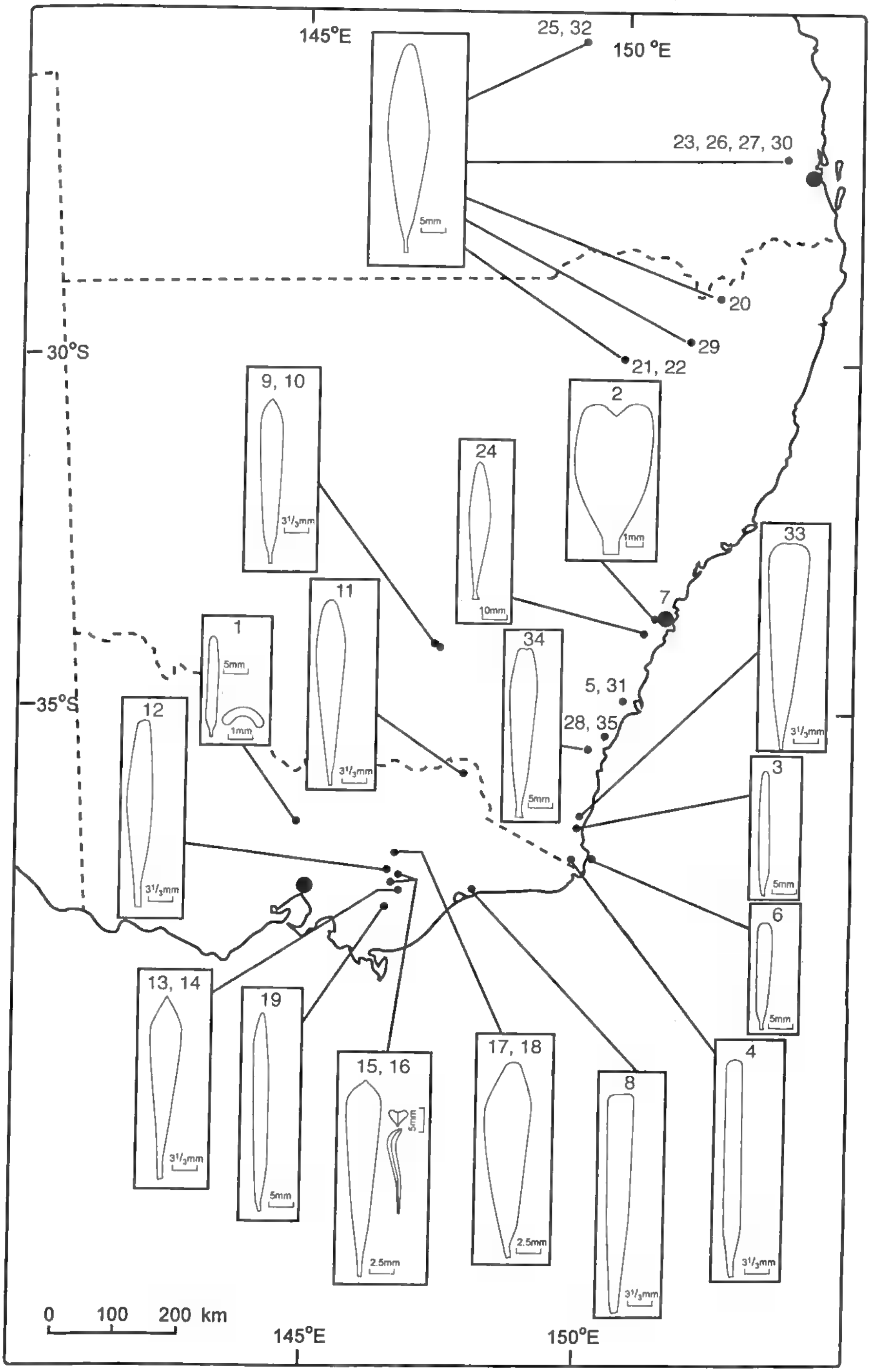

Fig. 1. Locations of populations of *Crowea exalata* sampled for study and illustrations showing leaf variation. Cross section of leaf shown for populations 1 and 15/16, and side view of leaf shown for population 15/16. See Table 1 for collection details of samples 1–35.

but the sampling regime did not cover the full geographic range of the three species, contributing to the knowledge of the oil composition of *Crowea* but having little taxonomic value as their study did not attempt to correlate oil composition with morphology. In the related genus *Eriostemon*, the rationale for reinstating *E. banksii* to species level was based in part on volatile oils data. The use of volatile oils by Brophy et al. (1997) and Bayly et al. (1998), and a review by Ghisalberti (1997) on the phytochemistry of *Boronia* Sm., *Eriostemon* and *Phebalium* species, reinforces the value of volatile oils as a character in this study.

Phenolics, like volatile oils, are under strict genetic control (Harborne & Turner 1984) and have been used in many studies because they are very stable and show very little ontogenetic or seasonal variation (Leach & Whiffin 1989). Unlike volatile oils, flavonoid analyses are usually qualitative, in terms of presence or absence on two-dimensional paper chromatography: therefore any seasonal or ontogenetic changes in the quantity of the compounds are hard to detect (Leach & Whiffin 1989). Prior to this study phenolic compounds have not been used as characters in the classification of *Crowea*.

In this study, the morphological variation within *C. exalata* was examined. The current literature suggests that subsp. *revoluta* shows the least amount of variation within this species in terms of flower and leaf size and shape, whilst subsp. *exalata* exhibits considerable variation in leaf size and shape across its geographic range (Wilson 1970, 1997; Duretto 1999). Wilson (1997) indicated that subsp. *revoluta* 'appeared' to grade with subsp. *exalata*. In addition to morphological analyses, the degree of chemical variation within *C. exalata* was assessed through investigation of the composition of the flavonoids and volatile oils.

Materials and Methods

Sampling: herbarium specimens of *C. exalata* were obtained from BRI, CANB, MEL, NE and NSW. Herbarium abbreviations follow Holmgren et al. (1990). In addition, 10 plants from each of 21 populations were sampled throughout the morphological and distributional range of the species (Fig. 1; Table 1). Leaves were collected from each plant and kept cool in polyethylene bags until processed for use in morphological and chemical analysis. Vouchers for all material are lodged at MEL with duplicates, where possible, distributed to CANB, LTB, NE and NSW.

Morphological Characters: ten leaves from each of the five plants per field population and 10 leaves from each of the 12 herbarium specimens (Table 1) were scanned using 'Morphosys' version 1.26 (Meacham & Duncan 1989). Four reference points were added to the scanned images. These points represented: 1-leaf base, 2 and 4-either side of the leaf at the widest point, and 3-leaf tip. An additional point, point 5, was automatically calculated as midpoint between 2 and 4 which represented the midpoint of the leaf where the leaf is widest. Seven leaf morphological characters were derived via 'Morphosys' (Table 2). Seven floral characters were measured for all taxa where material was available (using five replicates for each population). The floral characters were measured from field collections kept in 80% aqueous ethanol (80:20 – ethanol:distilled water) and from herbarium specimens. Due to the haphazard arrangement of the flowers on the herbarium specimens, it was not always possible to obtain five replicates

Table 1. Populations sampled for analyses.

Pop'n or spec No.	Collector No.	Herbarium	Location/ Sheet No.
1	Gebert 1–10	LTB & MEL	Whipstick SF, Vic., 36°41'S 144°17E
2	Olson 3997	NSW 257535	Budthingeroo Creek, NSW, 33°55'S 150°01'E
3	Gebert 11–20	LTB, MEL & NSW	Bournda Trig, NSW, 36°49'S 149°55'E
4	Gebert 128–137	LTB & MEL	Imlay Ck, NSW, 37°16'S 149°40'E
5	Gebert 127	MEL & NSW	Yalwal, NSW, 34°55'S 150°24'E
6	Gebert 21–30	LTB & MEL	Green Cape, NSW, 37°15'S 150°02'E
7	Constable s.n.	NSW 42706	Glenbrook, NSW, 33°46'S 150°37'E
8	Gebert 31–33	MEL	Nowa Nowa, Vic., 37°44'S 148°05'E
9	Gebert 70–79	LTB & MEL	Buddigower SF, NSW, 34°04'S 147°06'E
10	Gebert 80–89	LTB, MEL & NSW	Buggajool SF, NSW, 34°10'S 147°12'E
11	Gebert 90–99	LTB & MEL	Pine Mtn, Vic., 36°01'S 147°50'E
12	Gebert 178, 179	LTB, MEL & NSW	Macalister R., Vic., 37°27'S 146°33'E
13, 14	Gebert 148–167	LTB & MEL	Dolobrook Track, Vic., 37°44'S 146°45'E
15	Gebert 168–177	LTB & MEL	Wellington R., Vic., 37°31'S 146°39'E
16	Gebert 180–189	MEL & NSW	Dinner Ck Gorge, Vic., 37°31'S 146°40'E
17	Muir 735	MEL 4511	Dandongadale Falls, Vic., 37°03'S146°37'E
18	Gebert 190-199	LTB & MEL	Mt Howitt, Vic., 37°10'S 146°40'E
19	Gebert 117–126	LTB & MEL	Thompson R., Vic., 38°00'S 146°28'E
20	Gebert 34–43	LTB, MEL, NSW UNE	Emmaville, NSW, 29°15'S 151°34'E
21	Gebert 58–67	MEL	Waa Gorge, NSW, 30°04'S 150°06'E
22	Gebert 48–57	LTB, MEL, NSW UNE	Waa Gorge, NSW, 30°04'S 150°06'E
23	Forster PIF16398	BRI AQ634982	Mt Byron, Qld, 27°06'S 152°40'E
24	Gebert 100–109	LTB & MEL	Tahmoor, NSW, 34°15'S 150°35'E
25	Forster PIF17742	MEL 278735	Expedition NP, Qld, 25°20'S 149°11'E
26	Young 800	BRI AQ394796	Mt Byron, Qld, 27°00'S 152°40'E
27	Grimshaw G601	BRI AQ600852	Mt Byron, Qld, 27°06'S 152°40'E
28	Shoobridge s.n.	CANB 023972	Mogo SF, NSW, 35°47'S 150°04'E
29	Gebert 46	MEL	Howell, NSW, 29°57'S 151°02'E
30	Forster PIF17392	BRI AQ638096	Mt Mee SF, Qld, 27°07'S 152°41'E
31	Blaxell 1605	NSW 299859	Yalwal, NSW, 34°55'S 150°22'E
32	Forster PIF17759	BRI AQ638862	Expedition Range, Qld, 25°20'S 149°11'E
33	Gebert 110–116	LTB & MEL	Dr George Mtn, NSW, 36°40'S 149°54'E
34	Gebert 138–147	LTB & MEL	Coondella Trig., NSW, 35°56'S 149°54'E
35	Shoobridge s.n.	CANB 023969	Mogo SF, NSW, 35°47'S 150°04'E

Table 2. Morphological characters used in the phenetic analysis.

1. Leaf length (mm)
2. Leaf width (mm)
3. Distance to widest point from the base (mm)
4. Distance to widest point from the top (mm)
5. Distance to widest point from the base : Leaf length
6. Perimeter of leaf (mm)
7. Area of leaf (mm^2)
8. Petal length (mm)
9. Petal width (mm)
10. Petal width : Petal length
11. Pedicel length (mm)
12. Antesepalous stamen length (mm)
13. Antepetalous stamen length (mm)
14. Anther ratio

per specimen. Characters scored for the morphological analysis are listed in Table 2. Characters used were shown to be of use in delimiting taxa in other studies (eg. Wilson 1997) as well as from preliminary surveys.

Flavonoids: leaf material from five plants from each population was collected and analysed for flavonoid constituents. Leaves were air-dried for three to five days, then ground in a Waring blender and placed in air-tight glass jars until needed. Flavonoid extraction followed the procedures outlined in Mabry et al. (1970) and Markham (1982). Approximately 7 g of leaf material from each plant was placed in a 30 ml glass vial and covered with 80% aqueous methanol (80:20 – methanol:distilled water) and left to soak for 24 hours, being agitated once during this period. Approximately 335 µl of extract was applied to the chromatography sheet (Whatman 3MM chr 46 × 57 cm) over five applications, covering a circular area no greater than 3 cm diameter.

Two-dimensional paper chromatography was then carried out for each sample. The solvent used in the first dimension was a solution of tertiary butanol : glacial acetic acid : distilled water (3:1:1 v/v). The second dimension, which ran at 90 degrees to the first, utilised 15% aqueous Acetic Acid (15:85 – Acetic Acid:distilled water). All sheets were viewed over UV light (360 nm) in both the absence and presence of ammonia vapour. A spot on two different sheets was considered the same when colour changes and R_f values were similar. All compounds were arbitrarily assigned numbers as they were recognised. Compounds were scored as present or absent. No attempt was made to identify the compounds due to time constraints.

Volatile oils: leaf material was collected from five plants per population, where available, and the oil was extracted following the methodology of Newnham et al. (1986), Kottek et al. (1990), Whiffin and Bouchier (1992) and Whiffin and Ladiges (1992). The leaves were steam distilled in an all-glass apparatus to yield an oil-water mixture. The oil was separated from the water by mixing the oil-water mixture with twice distilled Freon 11 (trichlorofluoromethane, b.p. 23.7°C) in a separating funnel and allowing it to stand for two hours. The Freon-oil mixture was then decanted from the funnel, excess water was removed by adding anhydrous sodium sulphate and the sodium sulphate was removed by filtration, leaving an anhydrous mixture. The mixture was collected and distilled to remove most of the Freon with any excess being removed by applying high purity nitrogen over the surface of the oil. The capped vials of oil were stored at -20°C.

The oil samples were analysed using a Perkin-Elmer 8310 gas chromatograph with a 25 m × 0.23 mm fused silica column coated with BP225 (bonded OV101) and fitted with a flame ionisation detector. For each sample, a 0.2 µl sub-sample was injected, with the split ratio set to 1:100. The gas chromatograph was temperature-programmed from 50-180°C at an increase of 2°C per minute for 65 minutes. The injection temperature was 250°C and the detector temperature was 270°C.

A composite sample was also made up, consisting of a small sub-sample of oil from one plant per population. The composite was run every day to check for any changes in the gas chromatograph running conditions. One chromatograph obtained from the composite runs was used as the standard for chromatograms to be checked against. The peaks on the composite chromatogram were numbered consecutively from the beginning. Any peaks which were found on a sample chromatogram but not on the composite chromatogram were marked on the composite chromatogram and given a letter in the order in which they were found.

Tentative identification of the major compounds was attempted by comparing results herein with those of Brophy et al. (1997). Not all major compounds found in this study were able to be tentatively identified by comparison with Brophy et al. (1997) as some of the populations sampled in this study were not sampled by them.

Numerical analysis: each data set (available as PDFs from http://plantnet.rbgsyd.nsw.gov.au/Telopea); also given in Gebert 1999) was subjected to numerical analysis using PATN (Belbin 1987). For the morphological data set ratios (characters 4, 10, 14) were included as untransformed or as log-transformed data in different analyses. The ratios were removed from a third analysis. All averaged data were range-standardised, except for the volatile oil data as this would emphasise compounds of small quantities and bias the analysis (Whiffin 1982a, 1982b). Manhattan Metric (MM) distance matrices were calculated for all data sets as the appropriate similarity measure for continuous variables (Pimentel 1981, Belbin 1987). The resulting distance matrix was subjected to cluster analysis using unweighted pair-group method using arithmetic averages (UPGMA) and weighted pair-group method using arithmetic averages (WPGMA) as the fusion criteria to produce hierarchical dendrograms. Both cluster analysis strategies were utilised because UPGMA, where all OTU's have similar weight, is thought to be more accurate in the portrayal of relationships (Sneath & Sokal 1973), and WPGMA is useful when the groups of interest are of dissimilar size. Larger groups tend to dominate the analysis in UPGMA and so smaller groups can become distorted (T.Whiffin pers. comm.; M.Duretto unpub. data; cited in Duretto & Ladiges 1997). Principle co-ordinates analysis (PCoA) and Semi-Strong Hybrid Multidimensional Scaling (SSH-MDA), with cut-off values of 0.9 and 0.1, was carried out for all data sets.

Results

PCoA and SSH-MDA produced virtually the same results and only PCoA is discussed further below. Likewise, the three strategies utilized on the ratio data in the morphological data, viz. untransformed, log-transformed or deleted, produced virtually the same results and only the results using the untransformed ratios is presented below.

Plant Morphology: analysis of the leaf and floral morphology data clearly shows five distinct groups (M1-M5) in the UPGMA dendrogram (Fig. 2) and the WPGMA (not shown) and, though not as clearly, in the ordination (Fig. 3).

Group M1 contains population 1 from the Victorian Midlands. Group M2 consists of populations 3–19, which range from the Central Coast of New South Wales to Eastern Victoria. Group M3 contains population 2 from the Central Tablelands of New South Wales. Group M4 contains populations 20–34, which range from the South Coast of New South Wales to south-eastern Queensland, and Group M5 contains population 35 from the South Coast of New South Wales.

Flavonoids: a total of 39 phenolic compounds were found in the 18 field populations of *C. exalata* sampled after chromatographic separation. Of these 39 compounds, seven (1, 13, 14, 21, 22, 25, and 31) are common in all populations, four (37, 38, 39, and 40) were restricted to population 1, and compounds 12, 18, 20, 29, and 35 were restricted to populations 13 and 14, 4, 18, 3 and 6 respectively.

In the analysis three major groups (F1-F3) were recognised in the UPGMA (Fig. 4), WPGMA (not shown) and the ordination (Fig. 5). Group F1 is quite separate from Groups F2 and F3 and contains population 1 from the Victorian Midlands. Group F2 contains 13 populations ranging from the North Western Slopes of New South Wales south to the Snowfields of Victoria. Group F3 contains populations 19 and 15 from the Eastern Highlands of Victoria and population 34 from the South Coast of New South Wales.

Volatile Oils: a total of 231 volatile oil compounds were identified by gas chromatographic separation. Table 3 shows 5 major compounds and percent composition of each. These compounds are tentatively identified based on Brophy et al. (1997).

In the WPGMA (Fig. 6) and UPGMA (not shown) three major groups (V1-V3) are recognised and can be further divided into subgroups. Group V1 contains three subgroups; Group V1.1 contains three individuals from population 10, three individuals from population 15, and population 24; Group V1.2 contains population 19 and the remaining individuals from population 15; Group V1.3 contains a very tight cluster of individuals from population 22. Based on tentative identification Group V1 was found to contain high amounts of asaricin, except for population 19, which had low levels of all compounds (Table 3).

Group V2 contained three subgroups. Group V2.1 is made up of the remaining two individuals from population 10 and one individual from population 13; Group V2.2 contains populations 11, 14, 20 and the remaining individuals from population 13; and Group V2.3 contains population 1. Group V2 was found to have high amounts of (E)-carpacin, except for population 1 which had low amounts of (E)-carpacin and higher amounts of asaricin. Population 20 also contained high amounts of (E)-methyl isoeugenol (Table 3).

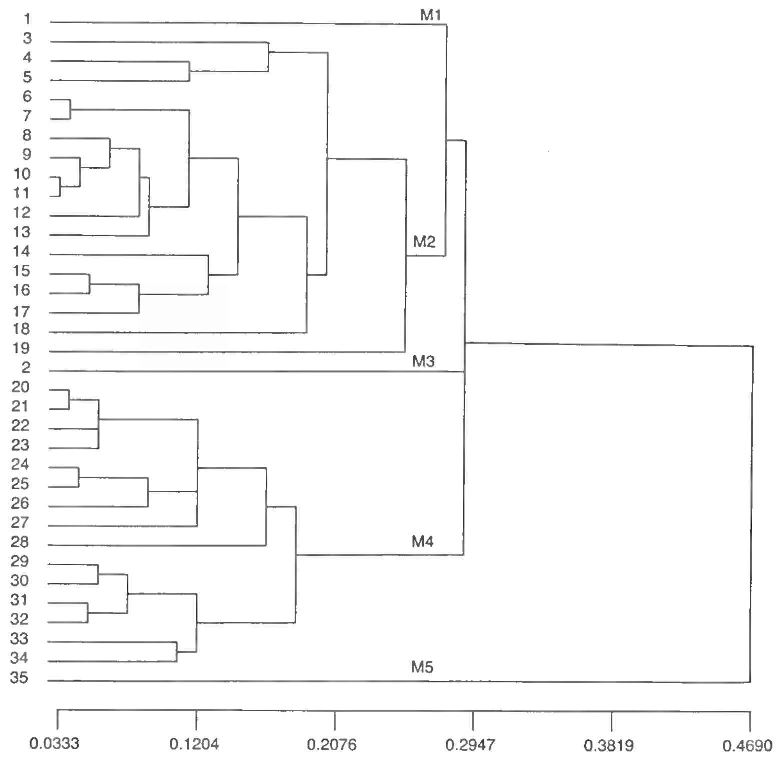

Fig. 2. Cluster analysis (MM, UPGMA), showing classification of *Crowea exalata* populations based on combined leaf and flower morphology data.

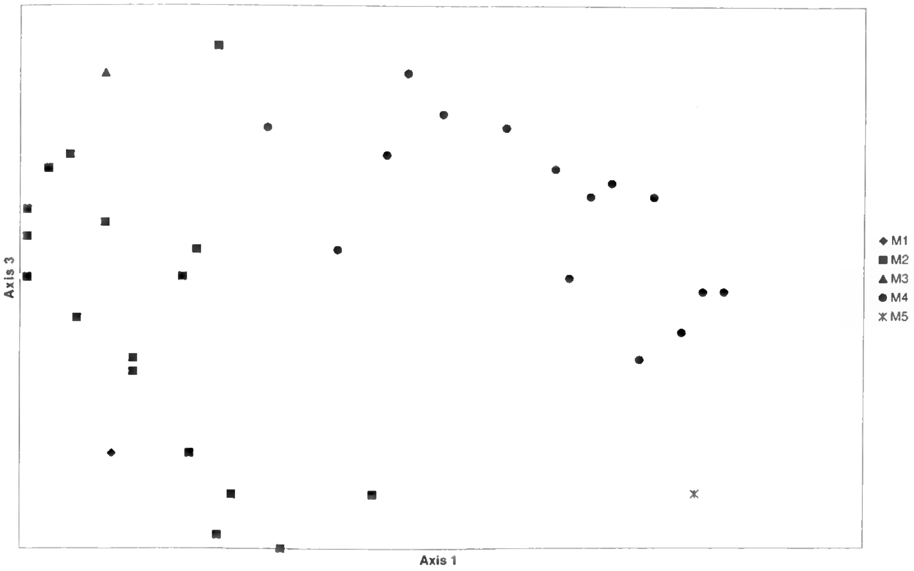

Fig. 3. Ordination (MM, PCoA) based on combined floral and leaf morphology data. Axis 1 accounts for 35% of the variation, and axis 3 accounts for 9%.

Group V3 contains two subgroups, all of which are from the South Coast of New South Wales, except for population 18 which is from the Snowfields of Victoria; Group V3.1 contains population 3, 18 and one individual from population 34; Group V3.2 has populations 4, 6, 33, and the remaining individuals from population 34. Group V3 was found to contain high amounts of croweacin and exalatacin (Table 3).

Table 3. Tentative identification of major volatile oil compounds (percent composition) found in samples used in this study; identifications based on Brophy et al. (1997).

	Volatile Oil				
Group & pop'n (voucher)	**croweacin**	**(E)-methyl isoeugenol**	**(E)-carpacin**	**asaricin**	**exalatacin**
Group V1					
10 (WG80 WG86, WG88)	4.1–24,			58–71	
15	0.07–1.1	0.02–0.28	0.02–0.37	29–88	
19	0.01–0.04	0.3–0.75	0.1–1.0	0.07–0.2	0.02–0.07
21, 22				3.9–6.5	
24	0.32	0.56	0.02–0.03	39–96	
Group V2					
1	0.03–0.1	0.36–1.4	0.16–0.7	1.8–3.4	0.09
10 (WG82, WG85)	1.9–2.4		0.04–0.05	0.25–1.0	0.1–0.25
11	0.08–0.58	0.08–0.32	20–44	0.15–1.4	0.06
13, 14	0.01–0.07	0.16–0.32	20–83	0.02–0.4	0.05–0.11
20	0.03	29–40	38–44	0.1–0.14	0.02–0.08
Group V3					
3	66–90	0.03	0.02	0.01–0.3	8.1
4	2–13.35	0.09–0.42	0.09–0.13	0.07–0.1	63-81
6	2.5–16.5	0.1	0.08–0.13	0.25–0.4	68-75
18	44–70	0.03–0.07	0.03–0.05	0.2–0.44	16-43
33	18–21	0.06–0.2	0.06–0.07	0.14–0.2	63-71
34	2.4–55	0.05–0.4	0.04–0.1	0.1–0.54	23-77

Discussion

In this study four taxonomic groups are recognised through numerical analysis of morphological (Figs 2, 3) and chemical flavonoid (Figs 4, 5) characters. The groups based on the morphological analysis (viz. Groups M1–M4) are discussed below. Groups M1–M4 are distinguishable on morphological characters, with chemical characters supporting the groups to a lesser extent. These groups are recognised here as subspecies, following the treatment of Wilson (1997). The placement of Group M5 is problematic (see discussion below).

Group 1 of both the morphological (M1; Figs 2, 3) and flavonoid analyses (F1; Figs 4, 5) is the population from the Whipstick State Forest (population 1), near Bendigo, in the Victorian Midlands (Fig. 1). It also formed a discrete group (V2.3) in the analysis

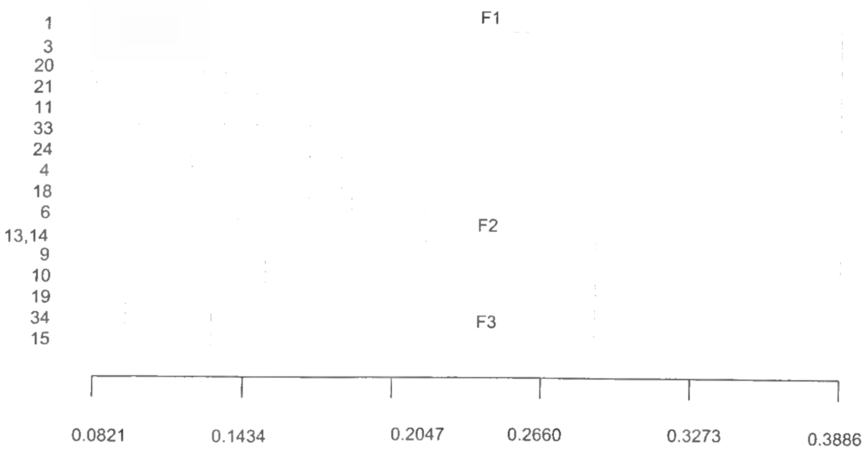

Fig. 4. Cluster analysis (MM, UPGMA), showing classification of *Crowea exalata* populations based on flavonoid data.

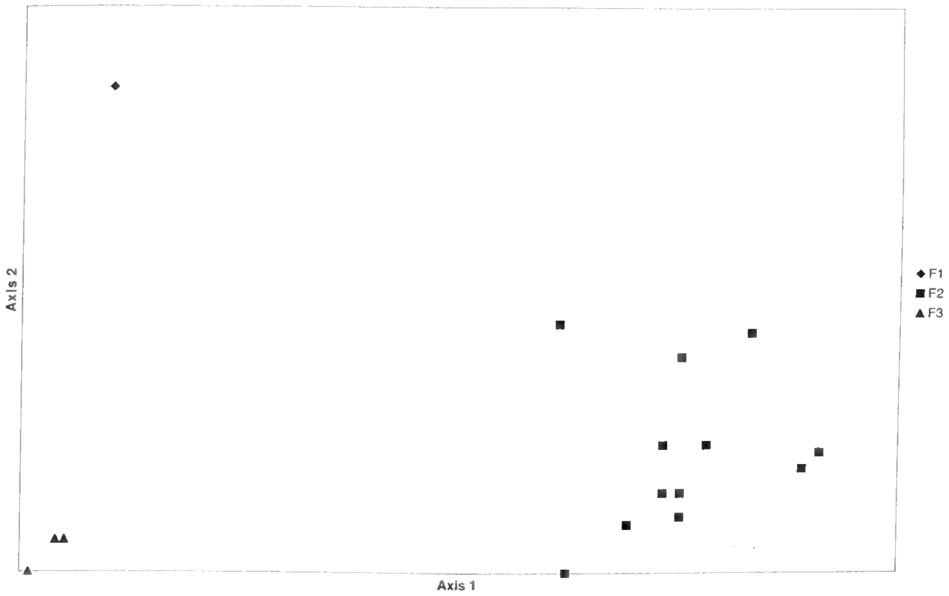

Fig. 5. Ordination (MM, PCoA) based on flavonoid data. Axis 1 accounts for 26 % of the variation, and axis 2 accounts for 16%.

of the volatile oil data. The characters separating Group M1 from the remaining groups are characters 2 (leaf width), 3 (distance to widest point from the base), 8 (petal length) and a revolute leaf margin (not scored). Group M1 can also be separated from Groups M3 and M4 by characters 1 (leaf length) and 6 (perimeter of leaf). Group M1 has the shortest petal length of this species, range of 5–8.5 mm with an average of 7 mm (char. 8), compared with other populations which range from 8–12mm with an average of 9.5mm. This group has four unique flavonoids and corresponds with *C. exalata* subsp. *revoluta* as described by Wilson (1997).

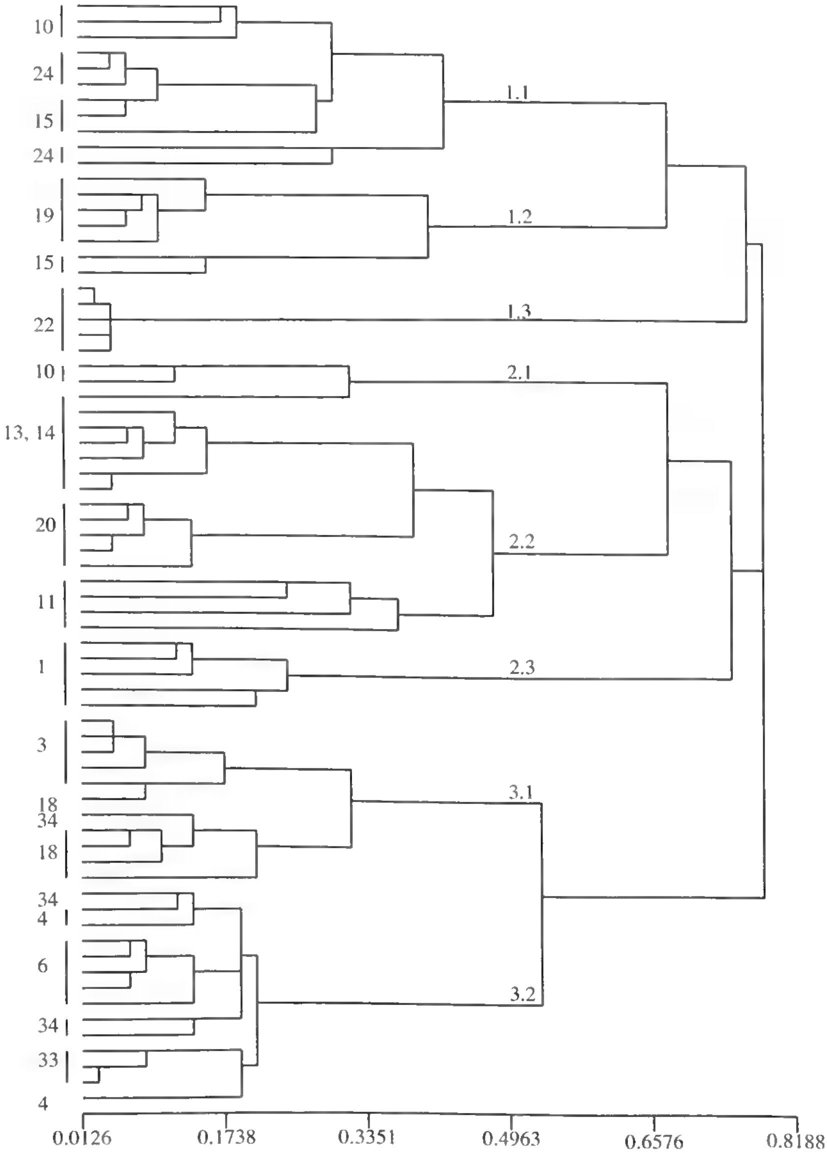

Fig. 6. Cluster analysis (MM, WPGMA), showing classification of *Crowea exalata* populations based on volatile oils data.

Group M2 contains populations 3–19 which are found in the Snowfields, Eastern Highlands, East Gippsland and the northeastern corner of the Midlands in Victoria and in the South Coast, Central Coast, Central and North Western Slopes and the Central Tablelands of New South Wales (Fig. 1). This group is separated from Group M3 by characters 1 (leaf length), 3 (distance to widest point from the base), 4 (leaf length:leaf width), and 6 (perimeter of leaf), and from Group M4 by characters 6 and 7 (area of leaf). The lectotype of *C. exalata*, which was not scored for the analysis because there was insufficient material, is from Mitta Mitta (see Wilson 1970, 1997) and matches this group: therefore, this group is *C. exalata* subsp. *exalata.*

Group M3 is the population from Boyd Plateau (population 2), Central Tablelands of New South Wales (Fig. 1). This group is distinguishable from Group M4 by characters 1 (leaf length), 3 (distance to widest point from the base), 5 (distance to widest point from the base:leaf length), and 7 (area of leaf). The obcordate leaf shape (not scored but reflected well in character five.) of this group is also a very good character that separates it from all other groups. The group was not sampled for either the flavonoid or volatile oil studies because of confusion with herbarium labels and so it could not be located in the field when field work was carried out. Wilson had not seen any material of this taxon when he completed his 1997 treatment. This group is newly described below as *C. exalata* subsp. *obcordata* Gebert.

Group M4 contains populations 20–35 from the South Coast, Central Coast, and the North Western Slopes of New South Wales and from the Leichhardt and Moreton Districts of Queensland (Fig. 1). This group is separated from Groups M1 and M3 by characters 1, 2, 3, 6 and 7 (see above and the key to subspecies below). This group is newly described below as *C. exalata* subsp. *magnifolia* Gebert.

Group M5 proved to be problematic in the morphological analysis (Figs 2, 3) by being a distinct group. It is made up of a single herbarium specimen found on the south coast of New South Wales. The region in which the specimen was collected was visited on several occasions to try to locate the population but to no avail. Group M5 is very similar to Group M4, and found within the geographic range of that group, but has slightly larger leaves and flowers (possibly a polyploid). In the ordination of the morphological data (Fig. 3), Group M5 clusters close to populations of Group M4. With this in mind Group M5 is considered to belong to the same taxon as Group M4, described below as *C. exalata* subsp. *magnifolia.*

Through this study it was found that the usefulness of flavonoids in the separation of taxa within *C. exalata* was limited. The flavonoid analysis (Figs 4, 5) shows that Group F1 (= M1), *C. exalata* subsp. *revoluta*, from the Victorian Midlands (population 1) can be readily distinguished from all other groups by having four unique flavonoids (see above). The remaining groups were not clearly defined by flavonoid composition. If an assumption can be made that the degree of flavonoid divergence is proportional to time since taxonomic divergence (a micromolecular clock), then these results suggests that *C. exalata* subsp. *revoluta* has been isolated from the other subspecies for the longest period of time. There was no evidence of a grade between this subspecies and *C. exalata* subsp. *exalata.*

Analysis of the volatile oils provided three major groups (V1-V3) and shows that the individuals in each population are chemically very similar. This is particularly noticeable in population 22 (Fig. 6) and could indicate a high level of interbreeding within each population. It was noted during field work that populations of *C. exalata* were usually small and isolated from other populations. In only one population (population 10) were two groups of individuals defined in the volatile oil analysis (V1, V2), suggesting that two chemotypes are present within this population. Of the three major groups, only in V3 were the populations geographically close, all of these, except population 9, are found on the South Coast of New South Wales between Moruya and Imlay Creek.

These findings are supported, to an extent, by the results published by Brophy et al. (1997). Brophy et al. (1997) described the essential oils of *Crowea* species and outlined five chemotypes for *C. exalata*. Although the sampling by Brophy et al. (1997) was mainly confined to Queensland and a few populations in New South Wales and the present study to New South Wales and Victoria, three of the chemotypes described by Brophy et al. (1997) correspond with the groups found here (Table 3). These are chemotypes two, four, and five. Chemotype two of Brophy et al. corresponds with Group V2, chemotype four of Brophy et al. with Group V1 and chemotype five of Brophy et al. with Group V3 (Table 3). This is no coincidence as four of the populations (24, 20, 34 and 6) sampled in this study were populations studied by Brophy et al. (1997). It was not possible to allocate the two remaining chemotypes of Brophy et al. to groups in this study as several locations in northern New South Wales and southeastern Queensland were not sampled.

Taxonomy

Crowea exalata F.Muell., *Trans. Philos. Soc. Victoria* 1: 11 (1855)

Type: Victoria: Eastern Highlands: Mitta Mitta River, *F. Mueller*, Feb 1854. Lectotype (*fide* Wilson, *Nuytsia* 1: 18 (1970)), MEL4410.

Shrub to 2 m high. Branchlets glandular, obtusely angular to subterete, puberulous in sunken lines between rounded ridges. Leaves sessile, entire, narrow-oblong to narrow-elliptic, rarely spathulate or obcordate, gradually narrowing to an attenuate base, 9–75 mm long, 1.5–9.5 mm wide, glabrous; apex acute to obtuse, mucronate to apiculate, rarely retuse or emarginate; lamina smooth, flat or with recurved margins, mid-vein slightly raised below. Flowers solitary, terminal to a short axillary shoot bearing few sub-apical leaves or shoot reduced to a short peduncle (to 1 mm long) with 2–5 small bracts; pedicel 1–4 mm long, sparsely puberulous. Calyx tube hemispherical; sepals imbricate, sub-orbicular to broad ovate, 2–2.5 mm long, puberulous to glabrous, ciliolate. Petals imbricate, thin, becoming chartaceous and broader in fruit, narrow- to broad-obovate, 5–14.5 mm long, 3–7 mm wide, white to pale mauve, turning reddish green with fruit, persistent. Stamens with sterile apices eventually spreading; filaments flattened, 2.5–3 mm long, pilose on the margins; anthers c. 1 mm long, appendage c. 2 mm long. Disc flat, forming a narrow lobed margin around ovary, dark green. Style short, thick, 0.5 mm long, pilose; stigma globular, c. 0.5 mm wide. Cocci glabrous, c. 7 mm long. Seed ovoid-reniform, 3.8–4 mm long; sclerotesta rugose, dull, dark brown to black. (Fig. 7)

Distribution and Ecology: *Crowea exalata* is a widespread species found in south-eastern Queensland, down the ranges and near coastal areas of New South Wales through eastern Victoria to the Bendigo area. The species is found in coastal to montane environments usually on well-drained soils or in rocky places in heath or *Eucalyptus* woodland. The inland populations are often found on clay-ironstone soils in box-ironbark woodlands.

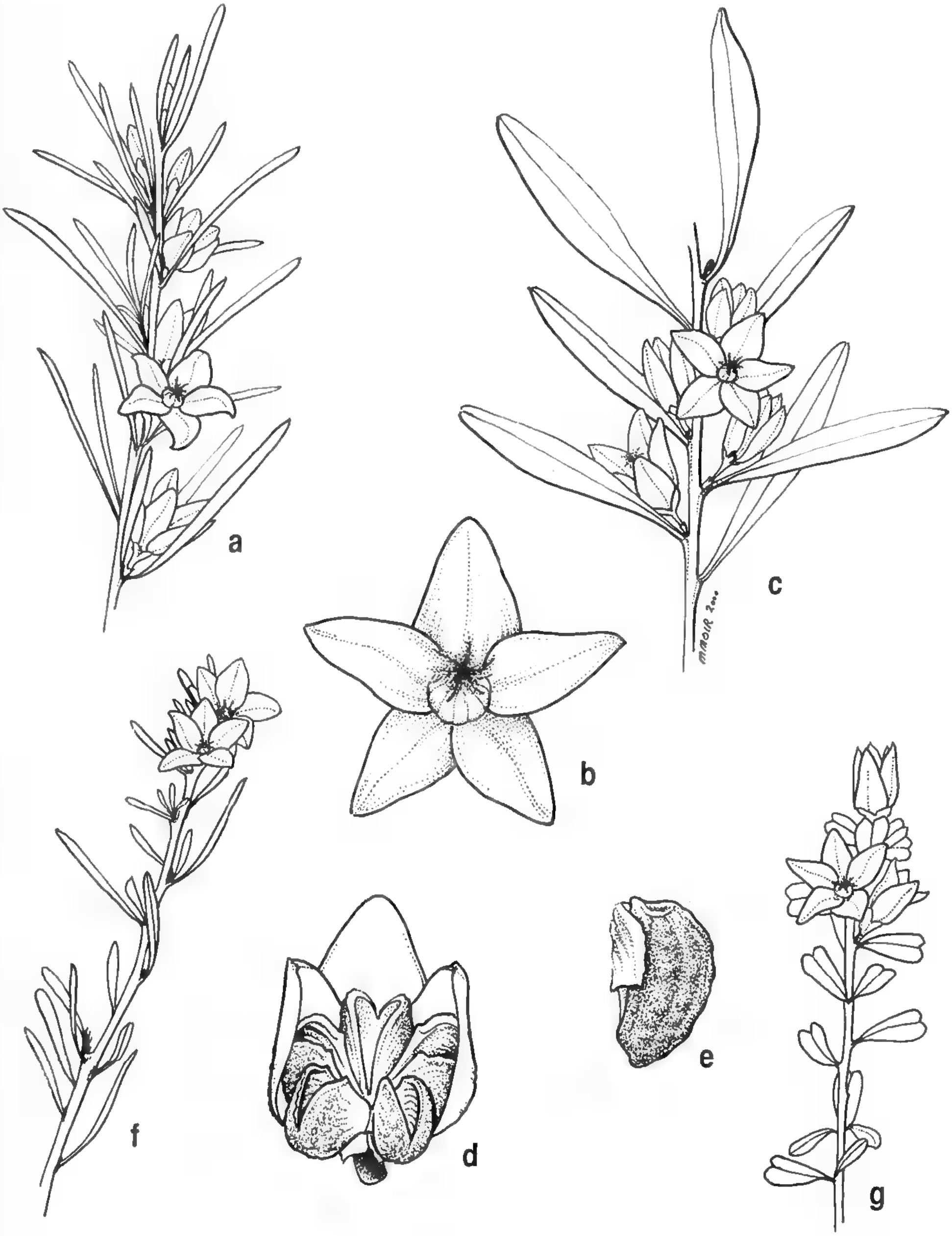

Fig. 7. a–g, *Crowea exalata*. **a–b,** subsp. *exalata*: **a,** flowering branchlet, ×1 (*James 479*, NSW); **b,** flower, ×3 (*Gebert 20*, MEL 2052865); **c–e,** subsp. *magnifolia*: **c,** flowering branchlet ×1, (holotype: *Grimshaw G601*, BRI AQ600852); **d,** mature fruit, perianth and stamens removed, ×3 ; **e,** seed, ×6 (d–e, *Gebert 48*, LTB); **f,** subsp. *revoluta*, flowering branchlet, ×1 (*Duretto 627*, MEL 2042763); **g,** subsp. *obcordata*, flowering branchlet, ×1 (holotype: *Olson 3997*, NSW 257535). Drawn by Mali Moir.

Key to subspecies

1 Leaves obcordate, leaf length less than or equal to twice the leaf width, 9–11 mm long (NSW, Central Tablelands) .... 4. subsp. ***obcordata***

1* Leaves narrow oblong to narrow elliptic, leaf length greater than three times the leaf width, 10–75 mm long (Vic., NSW, Qld) 2

2 Leaf lamina 13–23 mm long, 1.5–2.5 mm wide, margin revolute (Bendigo region, central Vic.) .... 3. subsp. ***revoluta***

2* Leaf lamina 10–75 mm long, 1.5–9.5 mm wide, margin flat to slightly recurved (Vic., NSW, Qld) 3

3 Leaves narrow-oblong to oblanceolate, sometimes narrowly elliptic or spathulate, 10–60 mm long, 1.5–6 mm wide, tip obtuse to acute (Vic., NSW) .... 1. subsp. ***exalata***

3* Leaves narrow-elliptic, rarely narrow-oblong to oblanceolate, 20–75 mm long, 3–9.5 mm wide, tip mucronate to apiculate, rarely acute or obtuse to retuse (southern populations) (NSW, Qld) .... 2. subsp. ***magnifolia***

1. *Crowea exalata* F.Muell. subsp. *exalata*

Illustrations: Duretto, *Flora of Victoria* 4: 180, Fig. 33a (1999); Weston & Harden, *Flora of New South Wales* 2, 2nd edn: 300 (2002).

Leaves narrow-oblong to oblanceolate, sometimes narrowly elliptic or spathulate, 10–60 mm long, 1.5–6 mm wide, margins flat to slightly recurved, tip obtuse to acute. *Pedicel* 1–4 mm long. *Petals* 7–14.5 mm long, 3–7 mm wide. (Fig. 7a, b)

Notes: leaf shape varies considerably within this taxon, from short and narrow to short and wide to long and narrow. Several populations near the Wellington River and Dinner Creek Gorge in the Victorian Eastern Highlands have a unique spathulate leaf that, when crushed, has a sarsaparilla scent, stronger than usual. This subspecies can be difficult to separate from subsp. *magnifolia* between Sydney and Eden (NSW), where the subspecies are broadly sympatric. Further work is required to determine if these subspecies are ecologically distinct or if there is a cline involved. It may be the case that some plants in this area will not be able to be determined to subspecies which is justification for using the rank of subspecies.

Distribution and Ecology: *Crowea exalata* subsp. *exalata* is found south from Sydney, New South Wales, and in eastern Victoria. The habitats it occupies vary from steep gorges, sandy capes, and alpine regions to rocky escarpments, usually where the soil is moist but well drained. Flowering (November) December-March (-July).

Conservation status: this subspecies is widespread, well represented in conservation reserves and does not appear to be under immediate threat.

Selected specimens examined: **New South Wales**: Central Western Slopes: Buddigower State Forest, c. 4.25 km E from Alleena train crossing on Newell Highway 34°03'S 147°05'E, *Gebert 70–79 & Mole*, 19 Sep 1998 (WG 70, 71, 73, 75, 78 - LTB, MEL; WG72 - MEL; WG 74, 76, 77, 79 - LTB); 2.25 km NNE Buggajool Trig., 34°09'S 147°12'E, *Gebert 80–89 & Mole*, 19 Sep 1998 (WG80 - LTB, MEL, NSW; WG81–89 - LTB). Central Coast: Glenbrook 33°46'S 150°37'E, *Constable s.n.*, 13 Nov 1957 (NSW). Southern Tablelands: Ginninderra Falls, lower falls, 200 m upstream from Murrumbidgee River 35°11'S 148°56'E, *Taws 394*, 27 Jun 1994 (MEL, NSW). South Coast: Bournda Trig Point, Bournda National Park 36°48'S 149°54'E, *Gebert 11–20 &*

Duretto, 27 Aug 1998 (WG11–12, 15–20 - LTB; WG13 - LTB, MEL, NSW; WG14 - LTB, NSW); Jingera Rock, Egan Peaks Nature Reserve 36°59'S 149°40'E, *Albrecht 2689*, 18 Jul 1986 (MEL); 900m from lighthouse entrance, Green Cape 37°15'S 150°2'E, *Gebert 21–30 & Duretto*, 27 Aug 1998 (WG21, 22, 24, 25, 27–30 - LTB; WG23 - LTB, NSW, MEL; WG26 - LTB, MEL); Imlay Creek / Wallagaraugh R, Newtons Crossing camp area 37°16'S 149°40'E, *Gebert, 128–131, 133–137*, 1 Dec 1998 (WG128 - MEL; WG129–131, 133–137 - LTB). **Victoria**: East Gippsland: Nowa Nowa. 37°44'S 148°05'E, *Gebert 31–33*, 29 Aug 1998 (MEL). Eastern Highlands: Pine Mountain, Burrowa-Pine Mt National Park. 36°01'S 147°50'E, *Gebert, 90–99 & Mole*, 20 Sep 1998 (WG90, 92–99 - LTB; WG91 - LTB, MEL); Beside Doldorook Track spur, S of Doldorook track junction with Ben Cruachan Ck, 37°44'S 146°45'E, *Gebert 148–167 & Mole*, 22 Dec 1998 (WG148–150, 152–158, 160–167 - LTB; WG151, 159 - MEL); Valleys of the Upper Macalister River 37°48'S 146°40'E, *Mueller*, Mar 1861 (MEL); MacAlister River, 1st crossing on Back Soil Gully track, N of Glencairn 37°28'S 146°33'E, *Gebert 178–179*, 29 Dec 1998 (WG178 - LTB, MEL, NSW; WG179 - LTB, MEL); Bruntons Bridge, Thompson River 38°00'S 146°28'E, *Gebert, 117–126*, 6 Nov 1998 (WG117–120, 123–126 - LTB; WG121–122 - LTB, MEL). Snowfields: Mt Wellington 37°30'S 146°51'E, *Littlejohn s.n.*, 10 Jan 1940 (MEL); saddle between Vallejo Ganther Hut and Mt Howitt on walking track 37°10'S 146°40'E, *Gebert 190–199*, 31 Dec 1998 (WG190-198 - LTB; WG199 - LTB, MEL)); Crosscut Saw between Mts Howitt and Speculation, 2.3km due north from Mt Howitt 37°9'S 146°38'E, *Walsh 2547*, 7 Jan 1981 (CANB, MEL); Dandongadale Falls, east of Mt Cobbler 37°03'S 146°37'E, *Muir 735*, 29 Mar 1959 (MEL); Dinner Creek Gorge, beside Bennison Plains Road, 13.6 km direct NNE from Licola 37°30'S 146°40'E, *Walsh 1799*, 19 Oct 1987 (CANB, MEL, NSW); Dinner Creek Gorge 37°31'S 146°40'E, *Gebert 180–189*, 29 Dec 1998 (WG180–186, 188, 189 - MEL; WG187 - MEL, NSW); Third crossing of Wellington River on walking track to Lake Tarli [=Tali] Karng 37°31'S 146°39'E, *Gebert 168–177 & Mole*, 22 Dec 1998 (WG168, 173 - LTB, MEL; WG169–172, 174–177 - LTB).

2. *Crowea exalata* subsp. *magnifolia* Gebert, *subsp. nov.*

A subspecie typica foliis anguste ellipticis 20–75 mm longis, 3–9.5mm latis, apicibus mucronatis vel apiculatis differt.

Type: Queensland: Moreton District: immediately below summit of Mt Byron, Mt Mee State Forest, 27°06'S 152°40'E, *Grimshaw G601* and *Figg*, 11 Apr 1994. Holotype: BRI AQ600852, transparencies MEL2172084.

[*Crowea saligna auct. non* Andrews: *sensu* EM Ross in TD Stanley and EM Ross, *Flora of South East Queensland* 1: 646 (1983)]

Illustration: Weston & Harden, *Flora of New South Wales* 2, 2nd edn: 300 (2002).

Leaves narrow elliptic, rarely narrow oblong to oblanceolate, 20–75 mm long, 3–9.5 mm wide, margins flat to slightly recurved, tip mucronate to apiculate, rarely acute or obtuse to retuse (southern populations). *Pedicel* 1.5–4 mm long. *Petals* 7.5–14 mm long, 3.5–7 mm wide. (Fig. 7 c–e)

Notes: *Crowea exalata* subsp. *magnifolia* has large and distinct oil glands on the abaxial surface of the leaves which are more apparent than those of the other subspecies. Leaves of most populations have a strong aniseed or sarsaparilla scent. This subspecies and the typical subspecies can be difficult to separate in populations between Sydney and Eden (NSW).

Distribution and Ecology: this subspecies is found from the South Coast of New South Wales north to south-eastern Queensland. It is found in moist but well drained soils. Flowering mainly October-April.

Conservation status: *Crowea exalata* subsp. *magnifolia* is widespread and well represented in conservation reserves (eg. Deua N.P., Mt Kaputar N.P., Expedition N.P.). It does not appear to be under immediate threat.

Etymology: the subspecific epithet is derived from Latin, *magnus* (large) and *folium* (leaf), and refers to the large size of the leaves, as compared to the other subspecies.

Selected specimens examined: **Queensland**: Leichhardt: Robinson Gorge, Expedition Range National Park 25°17'41"S 149°10'32"E, *Forster 17742 & Figg*, 17 Sep 1995 (MEL, NSW). Moreton: Dianas Bath, D'Aguilar Range near Mount Byron 27°06'S 152°40'E, *Forster 16398*, 4 Apr 1995 (MEL, NSW); State Forest 893, Mount Mee 27°06'54"S 152°41'28"E, *Forster 17392*, 4 Aug 1995 (MEL, NSW); Immediately below summit of Mt Byron, Mt Mee State Forest 27°07'S 152°40'E, *Grimshaw 601 & Figg*, 11 Apr 1994 (MEL). **New South Wales**: Northern Tablelands: Tributary of Flagstone Creek 29°17'S 151°34'E, *Gebert 34–43 & Mole*, 14 Sep 1998 (WG34 - LTB, MEL, NSW, UNE; WG35–43 - LTB); 4 km east of Howell on Tingha road 29°57'S 151°05'E, *Forster 16406 & Machin*, 21 Apr 1995 (MEL, NSW); Howell area, 50m E of Howell-Copeton Dam road, c. 50m N of Quart Pot Creek 29°56'S 151°02'E, *Copeland 2756*, 22 Nov 2000 (BRI, MEL, NSW); On roadside heading towards old mine which is 900m SE of Howell 29°57'S 151°02'E, *Gebert 46 & Mole*, 14 Sep 1998 (MEL); Waa Gorge, walking track on N side of Gorge, above Mill-Bullah water hole, Mt Kaputar National Park 30°04'S 150°06'E, *Gebert 48–57 & Mole*, 16 Sep 1998 (WG 48–53, 55–57 - LTB; WG54 - LTB, MEL, NSW, UNE); Top of Waa Gorge, Mt Kaputar National Park 30°04'S 150°06'E, *Gebert 58–67, & Mole*, 16 Sep 1998 (MEL); Yalwal 34°55'S 150°22'E, *Blaxell 1605*, 11 Apr 1978 (NSW). Central Coast: Tahmoor, Stratford Rd (end) adjacent to Bargo River, 34°15'S 150°35'E, *Gebert 100–109*, 14 Oct 1998 (WG100 - LTB, MEL; WG101–109 - LTB). South Coast: Yalwal 34°55'S 150°24'E, *Gebert 127*, 24 Nov 1998 (MEL); 1km N of Coondella Trig, Deua National Park 35°56'S 149°54'E, *Gebert 138–147 & Pearson*, 2 Dec 1998 (WG138, 141, 144 - LTB, MEL; WG139, 140, 142, 143, 145–147 - LTB); Dr George Mountain 36°40'S 149°54'E, *Gebert 110–116*, 15 Oct 1998 (WG110, 116 - LTB, MEL; WG111–115 - LTB); Nethercote Falls, Yowaka River, Nullica State Forest 36°59'S 149°49'E, *Albrecht 2290*, 13 Dec 1985 (MEL).

3. ***Crowea exalata*** subsp. ***revoluta*** Paul G.Wilson, *Nuytsia* 11: 430 (1997)

Type: Victoria: Midlands: 1 mile [1.6km] north of Lightning Hill near Eaglehawk, *D.L. Paton*, 18 Dec 1916. Holotype: MEL4413. Isotypes: MEL4414, MEL4415, MEL4416, MEL4417, MEL4418.

Leaves narrow oblong, 13–23 mm long, 1.5–2.5 mm wide, margins revolute, tip acute rarely apiculate. *Pedicel* 0.5–1.5 mm long. *Petals* 5–8.5 mm long, 3–4.5 mm wide. (Fig. 7f)

Distribution and Ecology: *Crowea exalata* subsp. *revoluta* is confined to the Midlands region, central Victoria, between Bendigo and Kamarooka, and also near St Arnaud. Found on clay-ironstone soils in Box-Ironbark communities. Flowers sporadically throughout the year.

Conservation status: Walsh and Stajsic (2007) considered this taxon to be vulnerable. Although not widespread, this subspecies is common in several reserves (eg. Whipstick, Kamarooka) around Bendigo and does not appear to be under immediate threat.

Etymology: the subspecific epithet is derived from Latin, *revolutus* (revolute or rolled back), and alludes to the leaf margins being rolled under the leaf.

Selected specimens examined: **Victoria**: Midlands: Western Whipstick, 1 mile north of Blue Jacket Reservoir 36°42'S 144°16'E, *Perry*, 3 Apr 1961 (MEL); St Arnaud 36°37'S 143°16'E, *Dale [ACB 3714]*, May 1951 (MEL); Reservoir on Lightning Hill Road [Bendigo], 36°46'S 144°16'E, *Robbins [ACB 38646]*, 12 Jul 1947 (MEL); Gobarup Flora Reserve 36°42'S 144°53'E, *Beauglehole 68932*, 4 May 1981 (MEL); Kamarooka State Park 36°31'S 144°23'E, *Beauglehole 69683*, 2 Nov 1981 (MEL); Trail to Flagstaff Hill, 17 km NW of Bendigo, Whipstick State Park. 36°38'S 144°15'E, *Jobson 3272*, 16 Oct 1994 (MEL); Foxes Bend Road, Whipstick Scrub 36°40'S 144°15'E, Duretto 627 & PG Neish, 1 Sep 1995 (MEL); Whipstick State Forest near Bendigo, 1km due N on Foxes Bend Rd from Whipstick Road 36°41'S 144°17'E, Gebert 1–10 & Whiffin, 11 Aug 1998 (WG1, 7 - LTB, MEL; WG2–6, 8–10 - LTB).

4. ***Crowea exalata*** subsp. ***obcordata*** Gebert, ***subsp. nov.***

A subspecie typica follis obcordatis 9–11 mm longis, 4–5.5 mm latis differt.

Type: New South Wales: Central Tablelands: Budthingeroo Creek, 33°55'S, 150°01'E, *I. Olson 3997*, 12 Apr 1992. Holotype: NSW257535, transparencies MEL2172083. Isotype: MEL2026011.

Illustration: Weston & Harden, *Flora of New South Wales* 2, 2nd edn: 300 (2002).

Leaves obcordate, 9–11 mm long, 4–5.5 mm wide, margins flat. *Pedicel* 3.5 mm long. *Petals* 7–9 mm long, 4.5 mm wide. (Fig. 7g)

Notes: *Crowea exalata* subsp. *obcordata* can be distinguished from all the other subspecies by its small, obcordate leaves.

Distribution and Ecology: this subspecies is found on the Boyd Plateau, Central Tablelands, New South Wales, near creeks. Flowering material has been collected in April.

Conservation status: *Crowea exalata* subsp. *obcordata* is known only from the type collection from Kanangra-Boyd National Park and a conservation code, following the format of Briggs and Leigh (1996), of 2KC is appropriate for this subspecies. Surveys are required to ascertain the extent of the known population.

Etymology: the subspecific epithet refers to the obcordate shape of the leaves.

Specimens seen: known from the type material only.

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Indigenous use of plants in south-eastern Australia

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Abstract

The removal of Indigenous people from their traditional lands in south-eastern Australia has rendered it necessary to collect much of the information about plant use from nineteenth century sources. Despite these difficulties, a fully referenced database of species occurring in Victoria which have known Indigenous use in some part of Australia contains over one thousand entries, approximately one third of the total native flora in the state. Databases have been assembled also for New South Wales, Tasmania and the higher rainfall areas of South Australia. They contain plants used for food, medicines, fibre, implements, adhesives and cultural purposes.

Underground storage organs constituted the major food source in higher rainfall areas, whereas seeds become more important in the arid lands. *Microseris lanceolata* (Walp.) Sch. Bip., and *Microseris scapigera* (Forst.) Sch.Bip., Murnong or Yam Daisy, widely used for food, present an interesting taxonomic and biogeographic study.

Introduction

Aborigines populated the south-eastern parts of the Australian continent at least 40,000 years before present. They depended on the use of the native flora and fauna for all of life's necessities, and their continued survival in Australia is evidence that they achieved a balance between exploitation and renewal of the resources. Since fire was regularly applied to significant parts of the landscape, there is no doubt that many of the patterns of biodiversity encountered by the European invaders were of Aboriginal creation. In setting high biodiversity as a goal of present-day management, this is not always acknowledged. (Gott 2005)

Methods

Since in south-eastern Australia Aboriginal people were soon displaced from their traditional lands and confined to reserves (Christie 1979), records of plant use often

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rely on European sources such as nineteenth century books (Smyth 1876), (Dawson 1881), (Curr 1886), and unpublished documents. Exact identification of species is sometimes difficult, but Smyth contains several lists of plants identified by Mueller. Knowledge of plant use still remains in Aboriginal communities and has been freely given (Mason unpublished, and many others). It has been possible to compile extensive Filemaker Pro databases of species for which there are records, written or oral. (Gott unpublished). These cover, separately, Victoria, New South Wales, Tasmania and the higher rainfall areas of South Australia and contain plants used for food, medicines, fibre, implements, adhesives and cultural purposes. Table 1 shows the number of species with recorded Indigenous use for the above purposes in New South Wales. Totalling all databases, there are 513 records covering approximately 1511 species. Copies are held by the Australian National Botanical Gardens, the Australian Institute of Aboriginal and Torres Strait Islander Studies, Canberra, and other organizations and individuals. This present paper deals with only a few examples of the utilised species or genera contained in the databases. For further details on the use of plants in Victoria see Gott (1993).

Table 1. Number of NSW plant species with recorded Indigenous use. From Gott (unpublished) NSWUSE database. Note that many species had more than one use.

Food	Medicine	Fibre	Implement	Adhesive	Other(incl. cultural uses)	Total
1248	496	159	260	103	260	1479

Food Plants – "roots"

Despite a popular view of hunting as the major food source, foods of vegetable origin were important in the diet (Gott 1982) and were always the fallback foods, gathered mainly by women and children.

In the higher rainfall areas of southeastern Australia, plant underground storage organs -"roots" in the broad sense - constituted the staple foods. The advantage of "roots" as staples is that they were available virtually year-round. William Buckley, the so-called 'wild white man' was a convict who escaped from the abortive settlement at Sullivan's Bay near Sorrento, Victoria, in 1803 and lived with the Wathaurong tribe around Geelong until 1834 (Morgan 1852). Throughout his account of life with the Wathaurong he constantly refers to 'roots' as the staple food, and this is borne out by many later observers.

' *their natural food consists of the meat of the country when they can kill it, but chiefly roots*' (T. Winter 1837 in Bride 1898).

'*They depend for food almost entirely on animals and roots*' (Dawson 1881)

The main sources of 'root' staples were small herbaceous perennials – geophytes that relied on underground storage to survive the dry hot summers, and some aquatics (Table 2). In the lower rainfall areas of south-eastern Australia and in the arid centre, seeds were more important as staples (Fig.1). Most of the species store carbohydrate in the roots as starch with amylose and amylopectin in varying proportions. However, some common Liliaceae sens.lat. (*Arthropodium, Bulbine, Caesia, Thysanotus* species)

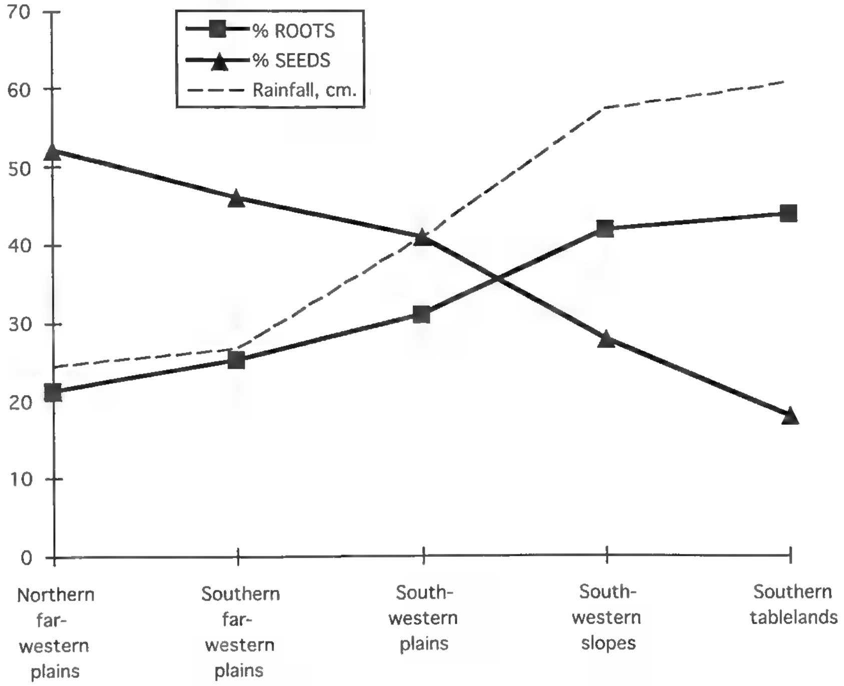

Fig. 1. Percentage of food plants providing roots and seeds from selected botanical divisions of New South Wales (source – Gott B. NSWUSE database).

and the most frequently mentioned Victorian staples, *Microseris lanceolata* and *M.scapigera,* store fructans – polymers of fructose (Table 2.) (Incoll et al. 1989). The occurrence of large amounts of fructans in pre-European Aboriginal diets could have implications for the high susceptibility of Aborigines to develop type 2 diabetes on European diets, which for them were exclusively starch-based (O'Dea 1986), (Englyst & Hudson 1997).

Of the several *Arthropodium* species, the most impressive is the informally named '*Arthropodium* species A' (Conran et al. 1993) (='*Arthropodium* species 1' of Conran 1994), found in alpine areas of New South Wales and Victoria. The tubers, which persist for more than a year, are particularly large and numerous (Fig. 2) and would have been available to tribes who frequented the high country in summer to feast on Bogong Moths, *Agrotis infusa* Boisduval. This *Arthropodium* species flowered spectacularly after the recent 2002–03 fires in the Kosciuszko National Park (New South Wales).

Although individual orchid species are rarely mentioned in historical records, orchid tubers as a general class were recorded as food; indeed they are still eaten in Europe (Kunkel 1984). The starch in orchid tubers is high in amylopectins, which would contribute to a relatively high Glycaemic Index. Some starch-containing roots such as *Pteridium esculentum* (G.Forst.)Cockayne and *Geranium* species would have been processed to break up the fibre content.

Table 2. Some food plants used for their "roots"

Family	Species	Storage Carbohydrate
Anthericaceae	*Arthropodium* spp.	fructans
Asphodelaceae	*Bulbine* spp.	fructans
Asteraceae	*Microseris lanceolata*	fructan (inulin)
Colchicaceae	*Burchardia umbellata*	starch
Colchicaceae	*Wurmbea* spp.	starch
Cyperaceae	*Bolboschoenus* spp.	starch
Dennstaedtiaceae	*Pteridium esculentum*	starch
Geraniaceaez	*Geranium* spp.	starch
Hypoxidaceae	*Hypoxis* spp.	starch
Juncaginaceae	*Triglochin procerum* sl	starch
Orchidaceae	All species	starch, high amylopectins
Phormiaceae	*Caesia* spp.	fructans
Typhaceae	*Typha* spp.	starch

Fig. 2. Tubers of *Arthropodium* sp. A (Conran et al. 1993)/sp. 1 (Conran 1994).

Aquatic Species

Typha domingensis Pers.and *T.orientalis* C.Presl were used widely for food and fibre along the Murray-Darling system and in the Victorian Gippsland Lakes (Gott 1999). The stele of the rhizome is packed with starch and has strong fibrous vascular bundles that were used for string. On the lower Murray River Charles French Angas remarked: '*The staff of their existence is the bulrush root…it is to them what bread is to the European*' (Angas 1847).

Triglochin procera R.Br. and related species have numerous soft root tubers that descend from the rhizome and are able to survive prolonged drought. They were an important food along the Murray River (Beveridge 1889), and were probably eaten all over Australia (Levitt 1982, Specht 1958). The hard corms of *Bolboschoenus* species were eaten after beating between stones. Young shoots and rhizomes of *Phragmites australis* Trin.ex Steud. were eaten by the Tasmanians (Peron F 1802 in Plomley 1983). The stems were most important for spears and necklaces, and well-grown material was traded down from the Murray River to southern Victoria.

Food plants – fruits and seeds

Fruits and seeds are seasonal only (Table 3), but were sometimes stored. Harvesting them would often result in big meetings with neighbouring tribes. An example of this is *Kunzea pomifera* F.Muell. (Fig. 3) which bears clusters of fragrant small pome-like fruits on the sandy coasts of western Victoria and South Australia (Dawson 1881). Along the Coorong the fruit was pounded into large cakes and traded to other tribes (Tindale 1981). It is at present becoming popular in the bushfood industry.

Nitraria billardieri DC. was another very popular fruit (Beveridge 1889) (Fig. 4) especially along the Murray River. It was notable around cooking mounds, presumably growing from discarded 'stones'. *Rubus parvifolius* L., *R.rosifolius* Sm., *Sambucus gaudichaudiana* DC., *S. australasica* (Lindl.) Fritsch and several *Solanum* species were widely eaten. *Solanum vescum* F.Muell. was greatly relished in Gippsland, Victoria (Mueller 1855). It can be managed as a fireweed, abundant after fire and disappearing after a few years only to re-appear with the next fire from the soil seed store.

Table 3. Some fruits and seeds used for food

Species	Used for
Acacia, selected spp.	seed ground, also eaten green
Eragrostis spp.	seed ground
Kunzea pomifera	fruit
Macrozamia communis	seed detoxified
Marsilea drummondii	sporocarp processed
Nitraria billardieri	fruit
Panicum spp.	seed ground
Portulaca oleracea	seed ground, stored
Rubus spp.	fruit
Sambucus spp.	fruit
Solanum vescum	fruit

Fig. 3. *Kunzea pomifera* fruits

Fig. 4. *Nitraria billarderi* fruit (both the dark and the light fruits are ripe).

In the drier areas, seeds of grasses were ground for flour, particularly *Eragrostis* and *Panicum* species. Seed of selected *Acacia* species was used; the lipid content of both the seed and the aril vary widely between species (O'Dowd & Gill 1986). *Portulaca oleracea* L. seed was stored for future use (Smyth 1878). *Macrozamia communis* L.Johnson seed required processing to remove toxins (Backhouse 1836). Nardoo, *Marsilea drummondii* A.Braun, is well known as the last food resource used by the explorers Burke and Wills before their deaths in July 1861 while on the Victorian Exploring Expedition. Less well known is that it contains an enzyme which destroys thiamine and may well have contributed to their deaths (McCleary & Chick 1977). For Aborigines it was only a fallback food, and was winnowed to remove the hard spore cases.

Other foods were "greens" from small herbs, nectar from flowers, gum from some Acacias and plant sap from lerp and manna. No sources of plant food were ignored, although some were resorted to only when more preferred foods were scarce. Table 4 lists some plants with uses other than food.

Table 4. Other plant uses.

Species	**Use**
Acacia dealbata/A.mearnsii	Fibre - bark
Amyema sp.	Medicine - steam bath
Carex tereticaulis	Fibre - stem
Centipeda spp.	Medicine
Duboisia hopwoodii	Medicine
Eucalyptus camaldulensis	Artefact - canoes
Eucalyptus spp.	Medicine - kino
Gynatrix pulchella	Fibre – outer stem
Lomandra longifolia	Fibre - leaf
Mentha australis	Medicine
Pimelea microcephala	Medicine - acupressure
Pimelea spp.	Fibre – outer stem
Xanthorrhoea spp.	Adhesive – resin

Medicine Plants

Records of medicinal plants in south-eastern Australia are less frequent than those from the northern Australian areas, where much traditional knowledge has been preserved (Low 1990, Aboriginal Communities of the Northern Territory 1993). Nevertheless, some northern species also occur in the south-east. Aromatic plants such as *Mentha* spp. (Lamiaceae) and *Centipeda* spp. (Asteraceae) species were widely used medicinally, often against the imported European diseases. Materials with high tannin content, such as Eucalypt kino (sap), were used on burns and wounds. The modern use of transdermal nicotine patches is mirrored by the placing behind the ear of chewed wads of Pituri, *Duboisia hopwoodii* (F.Muell.) F.Muell., a widely traded source of nornicotine (Watson 1983). Indeed aromatherapy with *Acacia* flowers (Plomley 1966), acupressure with string from *Pimelea microcephala* R.Br. (Koch 1898), steam baths with *Amyema* species (Stone 1911) and the application of medicines in smoke and as body-washes show that Aboriginal medicinal use of plants was varied and well-developed.

Fibre Plants

Fibre was used from a wide variety of species. Coarse string was made from the inner bark of large *Acacia* species and stringybark Eucalypts. *Typha* species were valued for the stelar fibres equally with their use for starchy food. Fine string to make the nets for catching Bogong Moths was prepared from *Pimelea axiflora* F.Muell.ex Meisn. and/or *P.pauciflora* R.Br. (Helms 1895). Fine coiled baskets continue to be made from the strong stems of *Carex tereticaulis* F.Muell. and baskets, string and eel traps came from leaves of *Lomandra longifolia* Labill. Buckets were made from whole bark pieces of *Acacia dealbata* Link and *A. mearnsii* De Wild.

Adhesives

A widely used adhesive was the waterproof resin from the leaf bases of *Xanthorrhoea* species. It was gently melted and mixed with fine fibrous material to make it less brittle.

Implements

Wooden implements such as boomerangs, spears, clubs, shields, digging sticks and containers are well represented in Museum collections. From ethnographic accounts and by direct microscopic sections it is sometimes possible to determine the species concerned (Smyth 1876, Kamminga 1988).

Microseris

Microseris lanceolata (Walp.) Sch. Bip., and *M. scapigera* (Forst.) Sch.Bip., Murnong or Yam Daisy constituted the staple food most commonly mentioned in early records (Gott 1983), and were abundant in dry sclerophyll woodlands and grasslands. In 1839 Thomas Mitchell (1839) reported the view over the plains of western Victoria as '*quite yellow with its flowers*' and G.A. Robinson, in north-central Victoria in 1840, referred to '*millions of murnong or yam all over the plain*' (Robinson in Clark 1998). Belonging to the Asteraceae, tribe Lactuceae, its leaves form a rosette, beginning growth in autumn from a stem-base to which are attached one or more soft tubers. New tubers form by the swelling of adventitious roots arising from the axils of the lower leaves. This applies to the 'Murnong' ecotype – see Table 5. For a discussion of the anatomy of the tubers see Gott 1983. At present it is proposed that there are two species, *M.lanceolata* and *M.scapigera* (Sneddon pers. comm. in Vijverberg et al. 2002).

Table 5. ***Microseris*** **ecotypes - after Vijverberg et al. (2002) (No species from Western Australia were included in the study.)**

Ecotype	Roots	Pappus	Fertilisation	Distribution
Murnong,M	short to long soft tubers from adventitious roots	scale	non selfing	VIC, NSW, SA
Alpine, A	long +/- tuberous adventitious roots producing new rosettes	scale	non selfing	VIC, NSW
Fine pappus F	Long fibrous +/- tuberous roots	fine	selfing	VIC, TAS, NZ
Coastal C	fibrous	narrow scale	selfing	NZ

The introduction by Europeans of hard-hoofed, close-grazing animals disastrously reduced the abundance of *Microseris*. Within 5 years of the founding of Melbourne it had disappeared from the surrounding area (Dredge1839–1843). Curr, writing of the northern Victorian plains in the 1840's said: *' Several thousand sheep not only learnt to root up these vegetables with their noses, but they for the most part lived on them for the first year, after which the root began gradually to get scarce'* (Curr 1886:240). The result today is that the occurrence of this genus is highly fragmented.

Genetics of *Microseris*

Recent work has suggested that Australian and New Zealand *Microseris* originated from western North America *"An allotetraploid (4x=36) which arose through hybridisation between an annual and a perennial diploid, followed by polyploidisation and long distance dispersal"* (Prober et al.1998) and has undergone adaptive radiation in Australia and New Zealand.

On the basis of genetic studies using chloroplast DNA, and detailed morphological studies, Vijverberg et al. (2002), have described four ecotypes: Murnong, Alpine, Fine pappus, and Coastal (Table 5). Vijverberg et al. conclude that 'the morphological diversification is accompanied by little genetic variation (Vijverberg et al.1999, 2000). *'The taxon is in a relatively early stage of adaptive radiation'* and that the *'process of adaptive radiation and morphological differentiation is progressing'.* They further state that the genetics indicate that *'an unambiguous classification of Australian and New Zealand Microseris is complicated at this early stage of adaptive radiation'.*

Indicative of this situation is that *M. lanceolata* in Flora of Victoria has been split into three informal species (Jeanes 1999).

It must be borne in mind that the populations of the various ecotypes have been long affected by human intervention. This particularly applies to the Murnong ecotype. Its tubers are non-fibrous, and at a shallow depth. As a preferred food for the Aborigines, it was subject to patch burning in late summer at intervals of approximately 3-5 years. This burning, both in dry sclerophyll woodlands and grasslands, ensured the maintenance of open sites for the growth of all the herbaceous perennial food plants (Gott 2005). Microseris and other food plants were also spread widely by trading (Morgan 1852).

The advent of European burning and grazing decimated and fragmented the populations of all the ecotypes, reducing the possibility of genetic interchange. Prober et al. (1998) found that, while isolated populations still retained allele richness, small populations were undergoing gradual genetic decline.

Microseris pollen

Pollen of the Lactuceae is distinct from other Asteraceae, and there are relatively few native species (c.10) that belong to the Lactuceae, including *Microseris* (Table 6). Lactuceae pollen appears in southern Australia during the upper Miocene (McPhail 1999). The possibility of tracing the evolutionary history of *Microseris* by distinguishing its pollen from other Lactuceae has been investigated but did not show promise (G. Crowley, L.Head, B.Gott, unpublished).

Table 6. Members of the Tribe Lactuceae native to South-eastern Australia

Actites megalocarpa	*Taraxacum*, 2spp
Cratystylis conocephala	*Sonchus hydrophilus*
Microseris lanceolata/scapigera	*Sonchus oleraceus*
Picris, 3 spp.	*Youngia japonica*

A final word

Aboriginal people have interacted with the Australian flora for many thousands of years. It is well to bear in mind that the evolutionary history of many of the species used by them may reflect that interaction.

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A synopsis of *Ptilotus* (Amaranthaceae) in eastern Australia

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Abstract

A synopsis is presented for the 31 *Ptilotus* species accepted by the author, and indigenous in eastern Australia (Queensland, New South Wales, Victoria and Tasmania). Notes on typification, distribution and habitat are given. Two new combinations are made, and 24 names are here formally reduced to synonymy. A lectotype is chosen for *P. calostachyus* F.Muell. A key to the identification of *Ptilotus* taxa in eastern Australia is included.

Introduction

Ptilotus is a genus comprising around 100 species, virtually confined to Australia, but with one species (*P. conicus* R.Br.) extending to Timor and adjacent islands. The majority of species occur in arid or semi-arid areas, with a centre of species diversity in Western Australia, where numerous species await formal naming. In eastern Australia (comprising Queensland, New South Wales (including Australian Capital Territory), Victoria and Tasmania), no undescribed species are known to occur.

In the latter half of the 20th century *Ptilotus* taxonomy was dominated by Gerhard Benl, a botanist based in Munich, Germany. He wrote many papers devoted to the taxonomy and nomenclature of *Ptilotus*, of which some of the main works were Benl (1958, 1959, 1967a, 1971, 1981).

Benl's apparent desire to document all observed morphological variation in a formal manner i.e. by describing new subspecies, varieties and formae of new or established species, based on one or few specimens, has resulted in a hideously complex nomenclature for the genus. While many of Benl's new species are "good", the infraspecific taxa, in very many cases, have proven to be of no practical taxonomic value, with the diagnosed differences being just part of the variation to be expected for a species. In addition, Australian users of Benl's papers have been hampered by the (often) German text, the cumbersome identification keys, and the sometimes erroneous, misleading or scanty diagnosis of taxa.

Ptilotus species (as with species of other genera and families) exhibit variation in many of their characteristics, both within and between populations. Often this variation is

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continuous and not correlated between characters, so that subdivision of species is meaningless and arbitrary. Perhaps because Benl was geographically remote from natural populations of *Ptilotus* and relied on intermittent specimen loans, he may never have seen the full range of variation exhibited by many species. Differences that appeared significant to him on one or a few specimens were often just part of the variation that is continuous within a species. The full range of variation can be observed only by seeing plants of different ages and sizes and from different regions and growing conditions. This is ideally achieved through field studies and observations, but a comprehensive set of herbarium specimens can be almost as informative. Through a combination of field work and herbarium study, the present author is confident of the synonymies and taxonomic concepts proposed in this paper.

The aim of this paper is to present a summary of the *Ptilotus* taxa in eastern Australia. Thirty one taxa of *Ptilotus* are accepted (29 species, one subspecies and one variety) as indigenous in eastern Australia. An identification key is provided, using readily observable characters. Two new combinations (*Ptilotus nobilis* subsp. *semilanatus* and *P. capensis*) are made here, 24 names are placed formally into synonymy and *P. calostachyus* is lectotypified.

Type specimens, or images of types, have been seen for nearly all taxa for which nomenclatural changes are proposed. Names based on types from Western Australia, South Australia and Northern Territory have not (with some exceptions) been considered in this treatment. Types not seen have been annotated with "n.v."

Specimens have been received on loan from AD, BM, CANB, K, MEL, and NSW and the entire holdings of BRI and MEL have been examined. In addition, images of type specimens have been received from B, CGE and LD. Tepal length measurements here include the fused basal portion, i.e. from the base of the perianth to the tip of the longest tepal. Accepted taxa are arranged in alphabetical order.

Taxonomy

Key to the eastern Australian taxa of *Ptilotus*

1 Inflorescences in the axils of fully-developed leaves; plants having the appearance of an *Alternanthera* or *Aerva*

  2 Tepals 2–3.5 mm long; bracteoles 1–2 mm long .... ***P. murrayi***

  2* Tepals 4–5 mm long; bracteoles 4–5.5 mm long .... ***P. decipiens***

1* Inflorescence terminal, or pseudo-terminal (i.e. borne in the axils of reduced upper leaves)

  3 Fully expanded leaves glabrous or with scattered hairs only

    4 Flowers at basal end of inflorescence widely spaced (> 3 mm apart)

      5 Tepals 12–15 mm long; leaves 35–70 mm long, margins entire; plant 50–70 cm high .... ***P. capensis***

      5* Tepals 9–11 mm long; leaves 8–15 mm long, margins undulate; plant up to 30 cm high .... ***P. extenuatus***

4* Flowers ± densely packed, <1mm apart

6 Tepals 17–44 mm long

7 Tepals with long septate hairs only .... ***P. macrocephalus***

7* Tepals with short verticillate[#] hairs as well as long septate hairs.................. .... ***P. nobilis* subsp. *nobilis***

6* Tepals 3–17 mm long

8 Tepals 10–17 mm long

9 Petioles (of the basal leaves) well-developed, always more than half lamina length and sometimes longer than lamina

10 Inflorescence cylindrical; tepals 10–14 mm long, pale green .... ***P. spathulatus***

10* Inflorescences globose to ovoid; tepals 12–15 mm long

11 Stems erect, to 40 cm high; tepals without short verticillate hairs; all tepal hairs septate, not exceeding ends of tepals........ .... ***P. indivisus***

11* Stems sprawling, to 30 cm high; verticillate hairs (0.2–1 mm long) present on tepals; longer tepal hairs septate, equalling or exceeding ends of tepals .... ***P. seminudus***

9* Petioles absent, obscure, or less than half lamina length

12 Outside of tepals with short verticillate[#] hairs as well as long septate hairs

13 Leaves rhombic, <10mm long .... ***P. remotiflorus***

13* Leaves linear to narrowly-oblanceolate, 20–50 mm long .... ***P. nobilis* subsp. *semilanatus***

12* Outside of tepals with unbranched septate hairs only

14 Inflorescence globose to ovoid, 1.5–4 cm long; leaves linear, up to 4 mm wide

15 Tepals curved; southern Australia .... ***P. erubescens***

15* Tepals straight; northern Australia .... ***P. fusiformis***

14* Inflorescence cylindrical, 3–12 cm long; leaves narrowly-lanceolate or lanceolate, 4–20 mm wide ... ***P. polystachyus***

8* Tepals 3–10 mm long

16 Lower leaves with distinct petiole as long as, or longer than lamina .. .. ***P. latifolius***

16* Leaves either without a distinct petiole, or petiole less than half the length of the lamina

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[#] verticillate hairs – those with a branching pattern very similar to an *Araucaria* tree (Norfolk Island Pine, for example), i.e. hair has a central 'column' with a number of verticillate branches

17 Distal half of tepals glabrous

18 Tepals white to pink when fresh, 3.5–4.5 mm long; peduncles 1–10 mm long, glabrous at 1 mm below base of inflorescence .... ***P. corymbosus***

18* Tepals red to maroon when fresh, 4.2–6 mm long; peduncles 30–130 mm long, sparsely hairy at 1 mm below base of inflorescence .... ***P. spicatus***

17* Tepals hairy throughout or almost throughout

19 Inflorescences pink to purple

20 Apex of tepals truncate, erose; plants to 30 cm high........... .... ***P. leucocoma***

20* Apex of tepals acute; plants 0.6–2.5 m high

21 Inflorescences erect, 1–4 cm long, apex rounded............ .... ***P. schwartzii***

21* Inflorescences ± pendulous, (3–)4–10 cm long, apex conical .... ***P. calostachyus***

19* Inflorescences white to greenish-white

22 Tepals almost completely obscured by white woolly indumentum .... ***P. brachyanthus***

22* Hairs present, but tepals readily visible

23 Procumbent sub-shrub to 20 cm high; leaves narrowly oblanceolate, sparsely hairy; bracteoles 3.5–4.5 mm long .... ***P. gaudichaudii* var. *parviflorus***

23* Erect shrub 25–60 cm high; leaves filiform, glabrous; bracteoles 2.5–3.5 mm long .... ***P. fusiformis***

3* All leaves conspicuously (often densely) hairy, at least on lower surface

24 Leaves orbicular; inflorescences in sessile clusters

25 Inflorescences globose to ellipsoidal; tepals 5–7 mm long; fully developed leaves 10–25 mm long .... ***P. maconochiei***

25* Inflorescences narrowly cylindrical; tepals 4–5 mm long; fully developed leaves 6–10 mm long... ***P. royceanus***

24* Leaves narrowly-lanceolate to broadly ovate; inflorescences pedunculate

26 All leaf hairs simple (uniseriate)

27 Tepals 16–21 mm long .... ***P. clementii***

27* Tepals 5–9 mm long

28 Tepals 7–9 mm long; filaments 3–4 mm long; anthers 0.45–0.6 mm long, at least some exserted on dried specimens; style 3.2–3.7 mm long .... ***P. helipteroides***

28* Tepals 5–7 mm long; filaments 1–1.8 mm long; anthers 0.2–0.4 mm long, none exserted on dried specimens; style 1–1.6 mm long .... ***P. pseudohelipteroides***

26* Leaf hairs stellate, dendritic or verticillate[#]

29 Tepals 10–17 mm long

30 Tepals deep pink; spikes 1–3 cm long .... ***P. sessilifolius***

30* Tepals white, grey or greenish; spikes 3–18 cm long ...***P. polystachyus***

29* Tepals 4–10 mm long

31 Leaves strongly discolorous, margins revolute; tepals 4–5 mm long .... ***P. pedleyanus***

31* Leaves ± concolorous, margins flat; tepals 5.5–10 mm long

32 Peduncles not branching, each 0–3 mm long, with inflorescences scattered along branchlets; lower leaves with very dense hairs 0.7–1.5 mm long .... ***P. incanus***

32* Peduncles branching, each 3–30 mm long, often giving rise to a corymbose conflorescence; lower leaves with moderate to dense cover of hairs 0.2–0.7 mm long .... ***P. obovatus***

Ptilotus brachyanthus (Benth.) F.Muell., Syst. Census Austral. Pl. 29 (1883)

Trichinium brachyanthum Benth., Fl. Austral. 5: 239 (1870).

Type: 'North-west Australia', 1856, *F. Mueller s.n.*; holo MEL; iso K.

Elliot & Jones, Encycl. Australian Pl., Volume 8: 104 (2002).

Ptilotus blakeanus Benl, Austrobaileya 1: 446 (1983), **syn. nov.**
Type: Queensland. Chesterton, 7 April 1936, *S.T. Blake 11107*; holo BRI.
Elliot & Jones, Encycl. Australian Pl., Volume 8: 104 (2002).-

Illustration: Benl (1983: 449, t. 30).

Distribution and habitat: there are pre-1900 records of *P. brachyanthus* from 'Peak Downs' (in 1872) and 'Burenda Downs' (late 1800's), both in Qld. In the 20th century, it was collected from a few places between Augathella and Longreach. It is otherwise known only from Mueller's type collection, presumably from the western part of the N.T. It is likely that the absence of records between Longreach and western N.T. is due to habitat modification and overgrazing. Habitat is poorly known but some collections describe the habitat as woodland dominated by *Acacia cambagei*.

Notes: *P. blakeanus* was described by Benl, based on a single specimen at BRI. He distinguished it from *P. brachyanthus* by the non-clustered spikes, the apical shape of the spikes, the colour of the inflorescence, the woollier stems, and the foliage being less dense. These characteristics are either trivial or continuously variable, and the variation exhibited by *P. brachyanthus* easily encompasses the type specimen of *P. blakeanus*.

Ptilotus calostachyus F.Muell., Fragm. 6: 231 (1868)

Trichinium calostachyum (F.Muell.) Benth., Fl. Austral. 5: 236 (1870); *Ptilotus calostachyus* F.Muell. var. *calostachyus*, Mitt. Bot. Staatssamml. München 2: 405 (1958).

Type: Western Australia. Roebuck Bay, undated, *J. Martin s.n.*; lecto MEL, **here chosen.** Benl, Fl. Cent. Austral. 82 (1981); Wheeler, Fl. Kimb. 124 (1992); Elliot & Jones, Encycl. Australian Pl., Volume 8: 104 (2002)..

Trichinium procerum Diels, Bot. Jahrb. Syst. 35: 191 (1904); *Ptilotus calostachyus* var. *procerus* (Diels) Benl, Mitt. Bot. Staatssamml. München 2: 405 (1958), **syn. nov.**
Type: Western Australia. De Witt, near Nichol Bay, undated, *L. Diels 2803*; holo B, digital image at BRI.

Illustrations: Erickson et al., Fl. & Pl. of W. Aust. 2nd edition 163 (1979); Elliot & Jones, Encycl. Australian Pl., Volume 8: 104 (2002); Moore, Guide Pl. Inland Australia 254 (2005).

Distribution and habitat: *P. calostachyus* is known from two localities north of Camooweal in Qld, both very close to the N.T. border. The species is widespread and common in central N.T. and the northern half of W.A. It inhabits sandy or stony plains and ridges.

Notes: Mueller cited three specimens in the protologue – one of his own, one by Martin and one by Walcott. The Mueller specimen could not be found at MEL. Of the two other syntypes, the Martin collection is the better quality specimen, and is here chosen as the lectotype.

Benl distinguished *P. calostachyus* var. *procerus* from *P. calostachyus* sens. str. by the supposedly longer spikes, bracts more hirsute and the smaller staminodial scales. When a range of specimens is examined, it is clear that these characteristics are variable and not correlated. The spike length and other macroscopic features on the type of *T. procerum* are typical for *P. calostachyus*, and furthermore the type locality of *T. procerum* coincides with that of one of the former syntypes of *T. calostachyus*.

Ptilotus capensis (Benl) A.R.Bean, ***comb. et stat. nov.***

Ptilotus distans subsp. *capensis* Benl, Austrobaileya 2: 17 (1984).

Type: Queensland. Thursday Island, June 1897, *F.M. Bailey 114*; holo BRI.

Bentham, Fl. Austral. 5: 223–4 (1870), *P. distans* in part; Elliot & Jones, Encycl. Australian Pl., Volume 8: 108 (2002), *P. distans* in part.

Illustration: Benl (1984: 18, fig. 1).

Distribution and habitat: *P. capensis* is endemic to Qld, extending on the islands of the Torres Strait, throughout Cape York Peninsula, and south to Kidston. It grows in open eucalypt woodland on shallow or deep sandy soils, or on reddish lateritic loams.

Notes: this taxon was given subspecies rank by Benl (1984). He distinguished *P. distans* subsp. *capensis* from *P. distans* sens. str. by the filaments 8–9.5 mm long (vs. 2.5–3 mm long for *P. distans* sens. str.), the style c. 7.5 mm long with an inconspicuous stigma (vs. style 1.3–2.2 mm long, stigma conspicuous and capitate), the hairs on top of the ovary erect, ciliate, articulate, to 3.3 mm long (vs. short spreading non-articulate pubescence to 1.4 mm long) and the outer surface of the bracts hairy throughout (vs. glabrous for *P. distans* sens. str.). I find that these differences are distinctive and consistent. In addition, the flowers of *P. capensis* are always stipitate, with stipes 0.5–1 mm long, while in *P. distans* sens. str. they are sessile. As was stated by Benl (loc. cit.), there is no intergradation between the two taxa. Hence specific rank is appropriate for this taxon.

Ptilotus clementii (Farmar) Benl, Mitt. Bot. Staatssamml. München 2: 405 (1958)

Trichinium clementii Farmar, Bull. Herb. Boissier ser. 2, 5: 1088 (1905).

Type: Western Australia. between the Ashburton and De Grey Rivers, 1897, *E. Clement*; holo K, n.v.

Benl, Fl. Cent. Austral. 79 (1981); Elliot & Jones, Encycl. Australian Pl., Volume 8: 105–6 (2002).

Ptilotus pearsonii C.T.White, Proc. Roy. Soc. Queensland 53: 225 (1942).
Type: Queensland. Soldier's Gap area, Cloncurry, July 1941, *S.E. Pearson 112*; holo BRI; iso GH, n.v.

Illustration: Moore, Guide Pl. Inland Australia 254 (2005).

Distribution and habitat: in eastern Australia, *P. clementii* is confined to the Mt Isa–Cloncurry area of north-west Qld. However, it is widespread in arid or semi-arid areas of N.T. and W.A., west to the Cape Range. It grows on stony hills in low open woodland dominated by eucalypts or acacias, or in *Triodia* grassland. Soils may be loamy or clayey.

Ptilotus corymbosus R.Br., Prodr. 415 (1810)

Trichinium corymbosum (R.Br.) Spreng., Syst. Veg. 1: 816 (1825), *non* Gaudich. (1829); *Ptilotus corymbosus* R.Br. var. *corymbosus*, Fl. Austral. 5: 243 (1870).

Type: [Northern Territory] Carpentaria Island 's' [Morgan Is.], 20–21 January 1803, *R. Brown [Bennett No. 3055]*; holo BM; iso K.

Bentham, Fl. Austral. 5: 242–3 (1870); Wheeler, Fl. Kimb. 124, 126 (1992); Elliot & Jones, Encycl. Australian Pl., Volume 8: 106 (2002).

Ptilotus corymbosus var. *acutiflorus* Benth., Fl. Austral. 5: 243 (1870), **syn. nov.**
Type: Northern Territory. North coast of Arnhem Land, 1862, *McKinlay s.n.*; holo MEL (2 sheets).

Illustration: Wheeler (1992: 127, t. 32A).

Distribution and habitat: *P. corymbosus* is confined (in eastern Australia) to the Lawn Hill area, north of Camooweal in north-west Qld. However, it is widespread in the northern half of N.T., and as far west as Broome in W.A. It typically inhabits stony ridges and hillsides with skeletal soil.

Ptilotus decipiens (Benth.) C.A.Gardn., *Enum. Pl. Austral. Occid.*: 41 (1930)

Alternanthera decipiens Benth., Fl. Austral. 5: 251 (1870).

Type: [Queensland] subtropical New Holland, 1846, *T.L. Mitchell 510*; holo ?K, n.v.

Benl, Fl. Cent. Austral. 80 (1981); Benl, Fl. South Austral. 1: 325 (1986); Elliot & Jones, Encycl. Australian Pl., Volume 8: 107 (2002).

Ptilotus hoodii F.Muell., Fragm. 8: 232 (1874).
Type: [Northern Territory] Mt Olga, 1873, *E. Giles s.n.*; holo MEL (2 sheets).

Distribution and habitat: *P. decipiens* has a rather scattered occurrence in western Qld as far east as Jericho, but is more common in arid parts of N.T. and S.A., and extends just into W.A. It grows on rocky hill slopes with skeletal soil.

Note: A.W.Hill, Index Kew. 8:199 (1933) is sometimes given as the secondary author, on the grounds that Gardner's combination (in Enum. Pl. Austral. Occid., 1930) was not validly made because he failed to adequately refer to the basionym. However, Article 33.2 of the Code (see also Ex. 5) states that, before 1953, an indirect reference to a basionym is sufficient for valid publication of a new combination.

Ptilotus erubescens Schltdl., Linnaea 20: 575 (1847)

Trichinium erubescens (Schltdl.) Moq. in A.DC., Prodr. 13(2): 293 (1849).

Type citation: South Australia. Dry hills near Gawlertown, undated [1844–47], *H.H. Behr s.n.*; holo ?HAL, n.v.

Cunningham et al. (1981: 285); Jacobs & Lapinpuro, Fl. N.S.W. 1: 259 (1990); Elliot & Jones, Encycl. Australian Pl., Volume 8: 109 (2002).

Illustrations: Jacobs & Lapinpuro (1990: 259); Walsh (1996: 211, t. 37m–n).

Distribution and habitat: *P. erubescens* is found in S.A., from the Flinders Ranges to south of Adelaide, and in the western half of Vic., and extending just into N.S.W. (near Deniliquin). It grows in grassland and woodland communities on relatively fertile soils.

Ptilotus extenuatus Benl, Telopea 2: 147 (1981)

Type: New South Wales, *anno* 1818, *C. Fraser 54*; holo BM, n.v., fide Benl, Telopea 2: 147 (1981).

Jacobs & Lapinpuro, Fl. N.S.W. 1: 257–8 (1990); Elliot & Jones, Encycl. Australian Pl., Volume 8: 110 (2002).

Illustrations: Benl, Telopea 2: 149–50, Fig. 1, 2 (1981); Jacobs & Lapinpuro (1990: 258).

Distribution and habitat: just four widely scattered collections of *P. extenuatus* have been made. In N.S.W., it is known from the type and one other collection. In Qld it has been collected twice in the far south of the state. The habitat is unknown. One specimen label records the soil as 'grey silty clay' while another says 'light sandy soil'.

Note: this species is listed as 'Presumed Extinct' in New South Wales, under the Threatened Species Conservation Act in that state.

Ptilotus fusiformis (R.Br.) Poir. in Lam., Encycl. Suppl. 4: 619 (1816)

Trichinium fusiforme R.Br., Prodr. 415 (1810); *Trichinium fusiforme* R.Br. var. *fusiforme*, Pl. Preiss. 1: 627 (1845); *Trichinium fusiforme* var. *typicum* Domin, Biblioth. Bot. 89: 82 (1921), nom. illeg.; *Ptilotus fusiformis* (R.Br.) F.Muell. var. *fusiformis*, Mitt. Bot. Staatssamml. München 3: 36 (1959).

Type: [Northern Territory] island in the Gulf of Carpentaria [North Island], 16/17 December 1802, *R. Brown [Bennett No. 3052]*; holo BM; iso MEL.

Bentham, Fl. Austral. 5: 234–5 (1870); Benl, Fl. Cent. Austral. 82 (1981); Wheeler, Fl. Kimb. 126, 128 (1992); Elliot & Jones, Encycl. Australian Pl., Volume 8: 110–11 (2002).

Trichinium gracile R.Br., Prodr. 415 (1810); *Ptilotus gracilis* (R.Br.) Poir. in Lam., Encycl. Suppl. 4: 620 (1816); *Trichinium fusiforme* var. *gracile* (R.Br.) Domin, Biblioth. Bot. 89: 82 (1921) *Ptilotus fusiformis* var. *gracilis* (R.Br.) Benl, Mitt. Bot. Staatssamml. München 3: 36 (1959), **syn. nov.**
Type: [Northern Territory] islands of the Gulf of Carpentaria [islands v, s & c], 1803, *R. Brown [Bennett No. 3053]*; holo BM; iso K, MEL.

Bentham, Fl. Austral. 5: 235 (1870).

Illustrations: Wheeler (1992: 127, t. 32E); Milson, Pasture Pl. N.W. Qld 11 (2000); Moore, Guide Pl. Inland Australia 256 (2005).

Distribution and habitat: *P. fusiformis* is very widely distributed across northern Australia, excluding high-rainfall or densely forested areas, from the Pilbara region of W.A., to around Collinsville in Qld. It inhabits a wide range of sites on sandy or loamy soils.

Notes: the *Ptilotus* combinations made by Poiret in *Encycl. Suppl.* appear to satisfy the requirements of Article 33.1 of the ICBN, because the generic epithet is definitely associated with the species epithet. Hence these combinations are validly published.

The type of *T. gracile* has tepals around 8 mm long, while the type of *T. fusiforme* has tepals 12 or 13 mm long. On that basis, Brown was quite justified in thinking there were distinct species. However, we now know that these collections represent the extremes of a continuum in tepal length for this species.

Ptilotus gaudichaudii var. ***parviflorus*** (Benth.) Benl, Mitt. Bot. Staatssamml. München 3: 36 (1959)

Trichinium corymbosum var. *parviflorum* Benth., Fl. Austral. 5: 226 (1870); *Hemisteirus psilotrichoides* F.Muell., Linnaea 25: 435 (1852); *Ptilotus hemisteirus* F.Muell., Fragm. 4: 90 (1864), nom. illeg.

Type: South Australia. Cudnaka, October 1851, *F. Mueller s.n.*; holo MEL.

Cunningham et al. (1981: 286), in part; Benl, Fl. South Austral. 1: 327 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 258–9 (1990); Elliot & Jones, Encycl. Australian Pl., Volume 8: 111 (2002).

Illustration: Jacobs & Lapinpuro (1990: 258, 259).

Distribution and habitat: in eastern Australia, *P. gaudichaudii* var. *parviflorus* is widespread in southern Qld and western N.S.W. It is also found in southern W.A. and S.A.

Note: *P. gaudichaudii* var. *parviflorus* is a decumbent plant to 25 cm high, with greenish-grey tepals 7–9 mm long, and narrowly spathulate leaves. From my own limited field observations and from examination of herbarium material, *P. gaudichaudii* var. *gaudichaudii* seems quite distinct from it. The latter is an erect plant to 60 cm, with bright yellow tepals 11–15 mm long, and filamentous leaves. Further study may reveal that these taxa are separable at species rank.

Ptilotus helipteroides (F.Muell.) F.Muell., Fragm. 6: 231 (1868)

Trichinium helipteroides F.Muell., Fragm. 3: 122 (1862); *Trichinium helipteroides* F.Muell. var. *helipteroides*, Fl. S. Austral. 2: 212 (1924); *Ptilotus helipteroides* (F.Muell.) F.Muell. var. *helipteroides*, Suppl. Fl. S. Austral. 2: 130 (1965)

Type: Western Australia. Nickol Bay, 1862, *P. Walcott*; holo MEL; iso MEL.

Bentham, Fl. Austral. 5: 231 (1870); Benl, Fl. Cent. Austral. 80 (1981); Benl, Fl. South Austral. 1: 327 (1986); Elliot & Jones, Encycl. Australian Pl., Volume 8: 112 (2002).

Illustrations: Erickson et al., Fl. & Pl. of W. Aust. 2nd edition 146 (1979); Elliot & Jones, Encycl. Australian Pl., Volume 8: 113 (2002); Moore, Guide Pl. Inland Australia 257 (2005).

Distribution and habitat: this species is widespread across arid Australia, from the west coast of W.A., southern N.T., northern S.A., and east to Boulia in western Qld. It inhabits grasslands, herblands or *Acacia aneura* open woodland on hills or plains, with red gravelly soils.

Ptilotus incanus (R.Br.) Poir. in Lam., Encycl. Suppl. 4: 620 (1816)

Trichinium incanum R.Br., Prodr. 415 (1810); *Trichinium incanum* R.Br. var. *incanum*, Proc. Roy. Soc. Victoria ser.2, 22: 97 (1909); *Ptilotus incanus* (R.Br.) Poir. var. *incanus*, Mitt. Bot. Staatssamml. München 3: 38 (1959).

Type: Western Australia. West coast of New Holland [probably Shark Bay], *anno* 1801, *O. Baudin s.n.*; syn BM.

Bentham, Fl. Austral. 5: 221–2 (1870); Benl, Fl. Cent. Austral. 79 (1981); Benl, Fl. South Austral. 1: 327 (1986); Wheeler, Fl. Kimb. 128 (1992); Elliot & Jones, Encycl. Australian Pl., Volume 8: 113–4 (2002).

Trichinium incanum var. *parviflorum* Ewart & Jean White, Proc. Roy. Soc. Victoria 22: 97 (1909); *Ptilotus incanus* var. *parviflorus* (Ewart & Jean White) Benl, Mitt. Bot. Staatssamml. München 3: 38 (1959), **syn. nov.**
Type: South Australia. NE of Mt Illillinna, Elder Explor. Exped. Camp 4, 9 June 1891, *R. Helms s.n.*; holo MEL.

Ptilotus incanus var. *elongatus* Benl, Mitt. Bot. Staatssamml. München 4: 278 (1961), **syn. nov.**
Type: Northern Territory. 52 miles [84 km] N of Tennant Creek township, 26 April 1948, *R.A. Perry 631*; holo CANB; iso BRI, MEL.

Ptilotus obovatus var. *griseus* Benl, Trans. Roy. Soc. South Australia 88: 58 (1964), **syn. nov.**
Type: Northern Territory. Mt Olga area, 16 August 1959, *E.N.S. Jackson 118*; holo AD; iso MEL.

Illustrations: Wheeler (1992: 129, t. 33A),

Distribution and habitat: in eastern Australia, *P. incanus* is confined to the Mt Isa–Cloncurry area of north-west Qld. However, it is widespread in arid Australia, including the Pilbara region of W.A., the southern N.T., and the northern parts of S.A. It grows on rocky hills with eucalypts or *Acacia* spp. and *Triodia* spp.

Notes: Benl maintained *P. incanus* var. *parviflorus*, originally established by Ewart and

White, and distinguished it from typical *P. incanus* by its fewer flowered inflorescences and the "loose" hairs on the stems and leaves. The inflorescences on the type specimen of *T. incanum* var. *parviflorum* are immature, and this alone accounts for the fewer visible flowers. There is no discernable difference in the indumentum pattern.

Benl erected another variety (var. *elongatus*); the type of this name has rather short hairs, as in *P. obovatus*, but features the sessile or subsessile inflorescences that are a feature of *P. incanus*. It is possibly a hybrid between these two species. The gradation of characters for *P. incanus* does not warrant the recognition of varieties within it.

Ptilotus indivisus Benl, Mitt. Bot. Staatssamml. München 3: 38 (1959)

Trichinium gomphrenoides Moq. in A.DC., Prodr. 13(2): 287 (1849); *Ptilotus gomphrenoides* (Moq.) F.Muell., Syst. Census Austral. Pl. 28 (1883), *nom. illeg., non* Benth. (1870).

Type Citation: "South Coast of New Holland, Drummond". **Type:** "S.C. of N. Holland, *Strutt [or Sturtt] s.n.*"; holo K.

Distribution and habitat: *P. indivisus* is known only from four specimens, all from the Mudgee and Parkes districts, on the central western slopes of N.S.W. The habitat is unknown.

Notes: I have examined the type specimen of *Trichinium gomphrenoides* from Kew. This specimen bears a slip saying "Trichin gomphrenoides Moq." in the distinctive handwriting of Alfred Moquin-Tandon, and it has been annotated by Benl as *P. indivisus.*

The person who wrote the label saying "S.C. of N. Holland, Strutt" for the holotype is unknown. It seems very likely that Charles Sturt is the collector intended, with the following as evidence: the geographical range of *P. indivisus* coincides with areas Sturt visited during his expeditions; there appears to be no record of a "Strutt" associated with botany or plant collecting in Australia; and the type of *P. leucocoma*, which undoubtedly *was* collected by Sturt, bears a label in the same handwriting, saying "N.W. interior N.H., Capt. Strutt".

As the type citation agrees so well with the label of the specimen at Kew (with the exception of the collector name), it seems likely that this is the holotype. Moquin stated that the type was "v.s. in h. Hook." or "seen dried in the Hooker herbarium". The Hooker herbarium is now incorporated in Kew. It is presumed that Moquin mistakenly wrote the name Drummond instead of Sturt.

Specimens that Benl determined as *P. indivisus* from the central western slopes of N.S.W. are a good match for the type. *Ptilotus indivisus* seems closely related to *P. seminudus*; their distributions apparently do not overlap in N.S.W., with *P. indivisus* occurring further to the east. There is an urgent need for field surveys to determine the current population size and extent of *P. indivisus*. On current knowledge, it should be regarded as an endangered species. There are just three specimens at NSW, with the most recent being 1964. The single specimen at MEL (from Mudgee) is dated 1880.

Ptilotus latifolius R.Br., Bot. Sturt's Exped. p. 88 (1849)

P. latifolius var. *latifolius*, Mitt. Bot. Staatssamml. München 3: 39 (1959).

Type: [Queensland?] in latitude 26°S, undated [1844–45], *C. Sturt s.n.*; holo BM.

Bentham, Fl. Austral. 5: 244 (1870); Benl, Fl. Cent. Austral. 80 (1981); Cunningham et al. (1981: 287); Benl, Fl. South Austral. 1: 328 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 259 (1990); Elliot & Jones, Encycl. Australian Pl., Volume 8: 114–5 (2002).

Ptilotus latifolius var. *major* Benl, Mitt. Bot. Staatssamml. München 3: 39 (1959), **syn. nov.**
Type: Western Australia. Hamersley Range, near Mt Rica, 26 October 1941, *C.A. Gardner 6429*; holo MEL; iso PERTH, n.v.

Illustrations: Cunningham et al. (1981: 287); Benl (1986: 325, t. 185B); Jacobs & Lapinpuro (1990: 259); Moore, Guide Pl. Inland Australia (2005: 257).

Distribution and habitat: a widespread species in arid parts of Australia from far western Qld and north-western N.S.W., across southern N.T. and northern S.A., to the Pilbara coast of W.A. It typically inhabits the crests of sand dunes, but may be present in other sandy free-draining locations.

Note: the variety *major* is well within the range of variation for the species, and specimens with the characteristics of var. *major* can be found in most populations of *P. latifolius.*

Ptilotus leucocoma (Moq.) F.Muell., Syst. Census Austral. Pl. 1: 29 (1883)

Trichinium leucocoma Moq. in A.DC., *Prodr.* 13(2): 292 (1849).

Type citation: "in Nova-Hollandia (herb. Hook!)". **Type:** N.W. [north-west] interior [of] N.H. [New Holland], undated [1828–29], *Capt. Strutt* [*C. Sturt s.n.*]; holo K.

Bentham, Fl. Austral. 5: 238 (1870); Benl, Fl. Cent. Austral. 80–1 (1981); Cunningham et al. (1981: 287); Jacobs & Lapinpuro, Fl. N.S.W. 1: 259 (1990); Elliot & Jones, Encycl. Australian Pl., Volume 8: 115 (2002).

Ptilotus calostachyus var. *kennediae* Ewart & Jean White, J. Proc. Roy. Soc. New South Wales 42: 193 (1908).
Type: New South Wales. Tandarlo via Wilcannia, Darling River, *anno* 1886, *W.B. Kennedy s.n.*; holo MEL.

[*Ptilotus kennediae* F.Muell., nom. nud.]

Ptilotus humifusus Benl, Sendtnera 1: 39 (1993), **syn. nov.**
Type: Queensland. 40 km S of Cunnamulla, 29 July 1983, *P.E. Conrick 1484*; holo AD; iso BRI, CANB, n.v.

Illustrations: Cunningham et al. (1981: 287); Jacobs & Lapinpuro (1990: 259); Benl, Sendtnera 1: 44, t. 2 (1993), as *P. humifusus*; Milson, Pl. Ident. in Arid Zone 29 (1995).

Distribution and habitat: *P. leucocoma* is mainly distributed from near Wilcannia in western N.S.W. to Windorah in Qld, but with two outlying localities, viz. Cloncurry, and 60 km W of Urandangie. Records from W.A. are likely to refer to another (probably unnamed) species. *Ptilotus leucocoma* grows on sandy-loam soils with *Acacia aneura* or on stony hills with *Eremophila* or *Senna* spp.

Notes: Chapman (1991) gave the spelling of the epithet as *leucocomus*, but as the epithet is a noun in apposition, it is not declinable as an epithet. Therefore *leucocoma* is correct.

The type of *P. humifusus* matches *P. leucocoma* in every way, and would appear to be merely a young plant of that species. Benl's epithet *humifusus* means 'creeping, prostrate'.

Prostrate and procumbent plants of *P. leucocoma* are readily found. It is significant that Benl did not diagnose *P. humifusus* against *P. leucocoma*, but only against *P. procumbens* from Western Australia.

Ptilotus maconochiei Benl, J. Adelaide Bot. Gard. 1: 201 (1979)

Type: Queensland. City lookout, Mt Isa, 8 March 1978, *G. Benl Au64 & J. Maconochie*; holo M, n.v.; iso BRI, MEL.

Elliot & Jones, Encycl. Australian Pl., Volume 8: 115 (2002).

Illustration: Benl, J. Adelaide Bot. Gard. 1: 202–3, t. 1, 2 (1979)

Distribution and habitat: *P. maconochiei* is endemic to Qld, where it is moderately widespread, though sporadic, from Mt Isa in the north to Windorah in the south. It grows on stony hills and residuals with *Acacia* spp.

Ptilotus macrocephalus (R.Br.) Poir. in Lam., Encycl. Suppl. 4: 620 (1816)

Trichinium macrocephalum R.Br., Prodr. 415 (1810).

Type: Australia. South coast, collector unknown; holo ?BM, n.v.

Bentham, Fl. Austral. 5: 225–6 (1870); Benl, Fl. Cent. Austral. 82 (1981); Cunningham et al. (1981: 287); Benl, Fl. South Austral. 1: 328 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 258 (1990); Wheeler, Fl. Kimb. 130 (1992); Walsh, Fl. Victoria 3: 209 (1996); Elliot & Jones, Encycl. Australian Pl., Volume 8: 116 (2002).

Trichinium angustifolium Moq. in A.DC., *Prodr.* 13(2): 293 (1849).
Type: New South Wales. Hunter's River, *A. Cunningham s.n.*; iso G-DC, microfiche.

Trichinium pachocephalum Moq. in A.DC., *Prodr.* 13(2): 294 (1849); *Ptilotus pachocephalus* (Moq.) F.Muell., *Fragm.* 6: 228 (1868).
Type: [Victoria]. Port Phillip, southern Australia, *?R. Gunn*; holo ?FI, n.v.

Illustrations: Cunningham et al. (1981: 287); Jacobs & Lapinpuro (1990: 258); Wheeler (1992: 131, t. 34B); Milson, Pl. Ident. in Arid Zone 29 (1995); Walsh (1996: 211, t. 37g–h); Elliot & Jones, Encycl. Australian Pl., Volume 8: 116 (2002); Moore, Guide Pl. Inland Australia 258 (2005).

Distribution and habitat: *P. macrocephalus* is very widespread in Qld, N.S.W. and Vic., mainly in arid areas, but also in some higher rainfall areas close to the coast. It is also widespread in S.A., N.T. and W.A. It grows in a wide range of habitats, including alluvium, stony plains and steep hills, but it is absent from cracking clay or coarse sandy soils.

Note: the tepal length (and hence the 'brush' or inflorescence width) is variable in this species. Plants with the longest tepals (up to 44 mm long) are found in north-eastern Queensland, while plants from other near-coastal areas of Qld and N.S.W. have tepals almost as long. Plants from W.A. have the shortest tepals, typically about 18 mm long. Examination of herbarium specimens from across the continent suggests that the variation is clinal.

Ptilotus murrayi F.Muell, Fragm. 3: 145 (1863

Ptilotus murrayi F.Muell. var. *murrayi*, Trans. & Proc. Roy. Soc. South Australia 47: 368 (1923).

Type: [state unknown]. From the flooded tracts of Wills Creek, beyond desert, 1861, *J. Murray s.n.*; holo MEL.

Bentham, Fl. Austral. 5: 243–4 (1870); Benl, Fl. Cent. Austral. 82 (1981); Benl, Fl. South Austral. 1: 328 (1986); Wheeler, Fl. Kimb. 130 (1992); Elliot & Jones, Encycl. Australian Pl., Volume 8: 118 (2002).

Ptilotus murrayi var. *major* J.M.Black, Trans. & Proc. Roy. Soc. South Australia 47: 368 (1923), **syn. nov.**
Type: South Australia. Between Herrgott and Innamincka, June 1916, *R. Cockburn s.n.*; holo AD [AD97747822A, left-hand specimen only].

Illustration: Wheeler (1992: 131, t. 34C).

Distribution and habitat: *P. murrayi* is common in south-western Qld, the far north-eastern part of S.A., and in the southern Kimberley region of W.A. Strangely, it is not yet recorded for the N.T. (D. Albrecht pers. comm. 2007). *P. murrayi* inhabits alluvial areas, favouring heavy cracking clay soil, often in association with *Eucalyptus coolabah* and *Chenopodium auricomum*.

Notes: the holotype of *P. murrayi* var. *major* is mounted on the same sheet as a collection made from the Diamantina River in August 1930. As the latter was collected after the publication of the name, only the left-hand specimen is type material.

Ptilotus murrayi var. *major* is not worthy of recognition as a separate taxon. Black separated his new variety based on the larger stems and leaves, the longer inflorescences 8–30 mm long and the perianth 3–4 mm long. The dimensions of the leaves and stems of the type are readily duplicated in other collections of *P. murrayi*. A couple of the inflorescences of the type do reach 30 mm long. This is longer than in most other collections of *P. murrayi*, but there is a continuum of inflorescence lengths, with no correlation to other characters. Black gave the perianth length as "3–4 mm", but the longest perianth I could find on the type measured 3.5 mm. This conforms with collections of *P. murrayi* from other parts of its range.

Ptilotus nobilis (Lindl.) F.Muell., Fragm. 6: 227 (1868)

Trichinium nobile Lindl. in T.Mitch., Three Exped. Australia 2: 23 (1838).

Type: New South Wales. "interior of New Holland" [Lachlan River, near Condobolin], 2 April 1836, *T.L. Mitchell 50*; holo CGE, digital image at BRI.

Bentham, Fl. Austral. 5: 224–5 (1870); Benl, Fl. Cent. Austral. 81 (1981); Cunningham et al. (1981: 288); Benl, Fl. South Austral. 1: 328–9 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 258 (1990); Walsh, Fl. Victoria 3: 209 (1996); Elliot & Jones, Encycl. Australian Pl., Volume 8: 118 (2002).

Ptilotus exaltatus Nees in Lehm., Pl. Preiss. 1: 630 (1845); *Trichinium exaltatum* (Nees) Benth., Fl. Austral. 5: 227 (1870); *Ptilotus exaltatus* Nees var. *exaltatus*, Census NSW Pl. 72 (1916), **syn. nov.**
Type: Western Australia. Avon River, between the farms of Messrs Heals and Whitfield, March 1840, *L. Preiss 1367*; holo LD, digital image at BRI.

Bentham, Fl. Austral. 5: 227 (1870); Cunningham et al. (1981: 285); Benl, Fl. South Austral. 1: 326 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 258 (1990); Wheeler, Fl. Kimb. 126 (1992); Walsh, Fl. Victoria 3: 212 (1996); Elliot & Jones, Encycl. Australian Pl., Volume 8: 109 (2002).

Notes: there has long been contention about the taxonomic difference or lack of difference between *P. nobilis* and the typical form of *P. exaltatus*. Bentham (1870) distinguished them by the presence or absence of woolly hairs on the inside of the tepals, but this character is not consistent. Benl (1971) additionally used the odour of the leaves as a distinguishing feature. The only other available difference has been flower colour, but populations have been found where both colour forms (pale yellow vs. purple) are present (M. Johnston, pers. comm. 2006).

Lee et al. (2007) have presented strong genetic evidence for the merging of these two species, a course that I have followed. However, it seems desirable to continue to recognise *semilanatus* as an infraspecific taxon, as it is readily morphologically distinguishable in most instances. The rank of subspecies is considered appropriate, as *P. nobilis* subsp. *nobilis* and *P. nobilis* subsp. *semilanatus* have separate "core" areas with a north-south zone of intergradation in central New South Wales and Queensland.

Two subspecies are recognised here:

a. **Ptilotus nobilis** (Lindl.) F.Muell. subsp. ***nobilis***

Trichinium densum A.Cunn. ex Moq. in A.DC., Prodr. 13(2): 289 (1849).
Type: New South Wales. Swampy-plains near Lachlan River, June 1817, *A. Cunningham s.n.*; holo G-DC, microfiche; iso CGE, digital image at BRI.

Trichinium macrocephalum Moq. in A.DC., Prodr. 13(2): 290 (1849), *nom. illeg.*, *non* R.Br. (1810).
Type: Western Australia. Careening Bay, 1820, *A. Cunningham 202*; iso BM.

Trichinium burtonii F.M.Bailey, Bull. Dept. Agric. Queensland 7: 14 (1891).
Type: Queensland. Between Camooweal and Urandangi towards Georgina R., *anno* 1890, *R.C. Burton s.n.*; holo BRI; iso MEL.

Trichinium nervosum F.M.Bailey, Queensland Agric. J. 25: 287 (1910).
Type: Queensland. Georgina River, September 1910, *E.W. Bick 51*; syn BRI; ditto, *E.W. Bick 50*; syn BRI.

Illustrations: Erickson et al., Fl. & Pl. of W. Aust. 2nd edition 146 (1979), as *P. exaltatus*; Cunningham et al. (1981: 285), as *P. exaltatus* var. *exaltatus*, (1981: 288); Benl (1986: 329, t. 186A); Jacobs & Lapinpuro (1990: 258); Wheeler (1992: 127, t. 32D); Milson, Pl. Ident. in Arid Zone 29 (1995), as *P. exaltatus* var. *exaltatus*; Walsh (1996: 211, t. 37e–f, o–p); Milson, Pasture Pl. N.W. Qld 10 (2000), as *P. exaltatus* var. *exaltatus*; Elliot & Jones, Encycl. Australian Pl., Volume 8: 117 (2002); Moore, Guide Pl. Inland Australia 255 (as *P. exaltatus*), 258 (2005).

Distribution and habitat: *P. nobilis* subsp. *nobilis* is widely distributed in W.A., N.T., S.A., far north-western Vic., western N.S.W. and western Qld. It is found in a variety of habitats, including *Acacia* woodland, mallee-eucalypt woodland, shrubland or grassland, on red sands, sandy loams or clays, occasionally on stony sites.

Note: flower colour may be purple-pink (plants previously known as *P. exaltatus* var. *exaltatus*) or creamy-white to greenish-white (plants previously known as *P. nobilis*). Both colour forms may be present in one population.

b. ***Ptilotus nobilis*** Nees subsp. ***semilanatus*** (Lindl.) A.R.Bean ***comb. et stat. nov.***

Trichinium semilanatum Lindl. in T.Mitch., J. Exped. Trop. Australia 45 (1848); *Ptilotus exaltatus* Nees var. *semilanatus* (Lindl.) Maiden & Betche, Census N.S.W. Pl. 72 (1916); *Ptilotus semilanatus* (Lindl.) J.M.Black, Fl. S. Austral. 2nd edition, 327 (1948)

Type: New South Wales. Duck Creek [c. 25 km N of Nyngan], subtropical New Holland, 27 January 1846, *T.L. Mitchell [*or *W. Stephenson] 74*; holo CGE, digital image at BRI; iso MEL.

Bentham, Fl. Austral. 5: 227–8 (1870); Cunningham et al. (1981: 286); Benl, Fl. South Austral. 1: 326 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 260 (1990); Walsh, Fl. Victoria 3: 212 (1996)

Trichinium pulchellum A.Cunn. ex Moq. in A.DC., Prodr. 13(2): 290 (1849).
Type: New South Wales. Swampy plains near Lachlan River, 20 May 1817, *A. Cunningham 20*; iso BM, digital image at BRI, G-DC, microfiche, GH, n.v.).

Trichinium setigerum A.Cunn. ex Moq. in A.DC., Prodr. 13(2): 290 (1849).
Type: New South Wales. Interior of eastern Australia, 25 May 1817, *A. Cunningham 19*; iso G-DC, microfiche.

Ptilotus dissitiflorus var. *longifolius* Benl, Muelleria 1: 107 (1959), **syn. nov.**
Type: Queensland. Port Denison [Bowen], 1874, *E. Fitzalan*; holo MEL.

Illustrations: Cunningham et al. (1981: 286), as *P. exaltatus* var. *semilanatus*; Jacobs & Lapinpuro (1990: 260), as *P. semilanatus*; Walsh (1996: 211, t. 37q–r), as *P. exaltatus* var. *semilanatus.*

Distribution and habitat: *P. nobilis* subsp. *semilanatus* is widespread in the eastern half of Qld, eastern N.S.W. and in northern and north-western Vic. It possibly also occurs in S.A. It intergrades with *P. nobilis* subsp. *nobilis*, with the latter occurring in the lower rainfall areas. The zone of intergradation is small compared with the overall distribution of *P. nobilis.*

Notes: this subspecies differs from the typical subspecies by the inflorescences 2–5(–8) cm long (5–20 cm long in subsp. *nobilis*), with the apex truncate or obtuse (conical in subsp. *nobilis*), the tepals 14–17 mm long (17–24 mm long in subsp. *nobilis*), and the linear or narrowly-spathulate leaves 2–6(–10) mm wide, with undulate margins (10–40 mm wide, margins straight in subsp. *nobilis*). It is consistently purple flowered (except for plants currently included under *P. nobilis* var. *angustifolius* Benl).

Ptilotus nobilis var. *angustifolius* Benl (the type of which comes from the Flinders Range, S.A.) is probably a synonym of *P. nobilis* subsp. *semilanatus*, but as I have not seen the type, no formal synonymy is given here.

The type of *P. dissitiflorus* var. *longifolius* indisputably belongs here. The flowers at the base of the inflorescences are rather widely spaced (unusual for *P. nobilis* subsp. *semilanatus*), but otherwise the type conforms in every regard with this subspecies. The type locality is given as Port Denison, the old name for Bowen. *Ptilotus nobilis* subsp. *semilanatus* is not known from the immediate vicinity of Bowen, but the collection was probably made some distance inland. Some other Fitzalan collections of non-coastal species are similarly labelled 'Port Denison'.

Ptilotus obovatus (Gaudich.) F.Muell., Fragm. 6: 228 (1868)

Trichinium obovatum Gaudich. in Freyc., Voy. Uranie Bot. 445, t. 49 (1829); *Trichinium obovatum* Gaudich. var. *obovatum*, Fl. Austral. 5: 221 (1870); *Ptilotus obovatus* (Gaudich.) F.Muell. var. *obovatus*, Fl. N. Territory 100 (1917)

Type: Western Australia. Baie des Chiens-Marins [Shark Bay], *C. Gaudichaud s.n.*; syn G-DC, microfiche, GH, n.v., P, n.v.

Bentham, Fl. Austral. 5: 220–1 (1870); Benl, Fl. Cent. Austral. 79 (1981); Cunningham et al. (1981: 288); Benl, Fl. South Austral. 1: 329–30 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 257 (1990); Walsh, Fl. Victoria 3: 208 (1996); Elliot & Jones, Encycl. Australian Pl., Volume 8: 118–9 (2002).

Trichinium parviflorum Lindl. in T.Mitch., Three Exped. Australia 2: 12 (1838); *Ptilotus parviflorus* (Lindl.) F.Muell., Syst. Census Austral. Pl. 1: 28 (1883); *Ptilotus obovatus* var. *parviflorus* (Lindl.) Benl, Mitt. Bot. Staatssamml. München 3: 512 (1960), **syn. nov.**
Type: New South Wales. Interior of New Holland [Byrne's Creek, N.S.W.], 24 March 1836, *T.L. Mitchell 24*; holo CGE, digital image at BRI.

Trichinium lanatum Lindl. in T.Mitch., Three Exped. Australia 2: 123 (1838); *Ptilotus lindleyi* F.Muell., Fragm. 6: 233 (1868).
Type: [Australia] Interior of New Holland [Murray River], 8 June 1836, *T.L. Mitchell 174*; holo CGE, digital image at BRI.

Trichinium virgatum Moq. in A.DC., Prodr. 13(2): 286 (1849).
Type: New South Wales. Swampy-plains near Lachlan River, July 1817, *A. Cunningham 17*; holo G-DC, microfiche; iso: K.

Trichinium variabile F.Muell., Linnaea 25: 436 (1853).
Type: South Australia. Barren plains between Flinders Range and Spencer Gulf, October 1851, *F. Mueller s.n.*; syn MEL (2 sheets).

Trichinium subviride Domin, Biblioth. Bot. 89: 81 (1921).
Type: Queensland. Near Cloncurry, January 1910, *K. Domin*; holo ?PR, n.v., fide Benl, Mitt. Bot. Staatssamml. München 3: 512 (1960).

Ptilotus obovatus var. *lancifolius* Benl, Mitt. Bot. Staatssamml. München 4: 279 (1961), **syn. nov.**
Type: Queensland. 13 miles [21 km] SSE of Kajabbi township, 29 August 1953, *M. Lazarides 4006*; holo CANB; iso BRI, MEL.

Illustrations: Cunningham et al. (1981: 288); Jacobs & Lapinpuro (1990: 257); Milson, Pl. Ident. in Arid Zone 29 (1995); Elliot & Jones, Encycl. Australian Pl., Volume 8: 104 (2002); Moore, Guide Pl. Inland Australia 259 (2005).

Distribution and habitat: *P. obovatus* is a very widespread species occurring in all mainland states, although in Vic. confined to the far north-west. It inhabits a wide range of sites, from steep stony hillsides to clayey flats, with a wide variety of associated species.

Note: the named varieties of *P. obovatus* are not worthy of recognition. Some are referable to other species (var. *griseus*, var. *grandiflorus*), while the others cannot be applied with any degree of certainty. While the species is very variable, there is no ecological or distributional pattern to the variation - plants with narrower leaves or smaller flowers or hairy ovaries can be found throughout the range of the species.

Ptilotus pedleyanus Benl & H.Eichler, Brunonia 4: 199 (1982)

Ptilotus pedleyanus var. *pedleyanus*, Brunonia 4: 205 (1982).

Type: Queensland. 'Grant' holding, NE of Barcaldine, July 1975, *G.R. Beeston 1450C*; holo BRI.

Elliot & Jones, Encycl. Australian Pl., Volume 8: 119 (2002).

Ptilotus pedleyanus var. *comosus* Benl & H.Eichler, Brunonia 4: 205 (1982), **syn. nov.** Type: Queensland. Cooladdi-Langlo Crossing road, 24 km N of Cooladdi, 1 October 1974, *R.G. Silcock 433*; holo BRI.

Distribution and habitat: *P. pedleyanus* is endemic to Qld, extending from Winton and Aramac in the north, to Quilpie in the south. It inhabits break-aways and other stony hills, with species such as *Acacia catenulata* and *Eremophila* spp.

Note: *P. pedleyanus* var. *comosus* is not worthy of recognition as a separate taxon. It represents minor variation within the species. Plants conforming to both of the named varieties can and do occur within the same population.

Ptilotus polystachyus (Gaudich.) F.Muell., Fragm. 6: 230 (1868)

Trichinium polystachyum Gaudich. in Freyc., Voy. Uranie Bot. 445 (1829); *Ptilotus polystachyus* var. *polystachyus*, Mitt. Bot. Staatssamml. München 7: 317 (1970); *Ptilotus polystachyus* f. *polystachyus*, Nuytsia 4: 273 (1983).

Types: Western Australia. Shark Bay, undated [September 1818], *C. Gaudichaud-Beaupre*; syn BM; syn G, n.v.; syn P, n.v., fide Benl (1983).

Bentham, Fl. Austral. 5: 225 (1870); Benl, Fl. Cent. Austral. 80 (1981); Cunningham et al. (1981: 289); Benl, Fl. South Austral. 1: 330–31 (1986); Wheeler, Fl. Perth Region 1: 97–8 (1987); Jacobs & Lapinpuro, Fl. N.S.W. 1: 257 (1990); Wheeler, Fl. Kimb. 130, 132 (1992); Walsh, Fl. Victoria 3: 208 (1996); Elliot & Jones, Encycl. Australian Pl., Volume 8: 120 (2002).

Trichinium alopecuroideum Lindl. in T.Mitch., Three Exped. Australia 2: 12 (1838); *Ptilotus alopecuroideus* (Lindl.) F.Muell., *Fragm.* 6: 227 (1868); *Trichinium alopecuroideum* Lindl. var. *alopecuroideum*, Trans. & Proc. Roy. Soc. South Australia 40: 61 (1916); *Ptilotus alopecuroideus* (Lindl.) F.Muell. f. *alopecuroideus*, Mitt. Bot. Staatssamml. München 2: 402 (1958).
Type: New South Wales. Interior of New Holland [Byrnes Ck, N.S.W.], 24 March 1836, *T.L. Mitchell s.n.*; holo CGE, digital image at BRI; iso BM, K, MEL.
Bentham, Fl. Austral. 5: 224 (1870).

Trichinium conicum Lindl. in T.Mitch., J. Exped. Trop. Australia 363 (1848), nom. illeg., non Spreng. (1824).

Trichinium alopecuroideum var. *rubriflorum* J.M.Black, Trans. & Proc. Roy. Soc. South Australia 40: 61 (1916); *Ptilotus alopecuroideus* f. *rubriflorus* (J.M.Black) Benl, Mitt. Bot. Staatssamml. München 2: 402 (1958); *Ptilotus polystachyus* f. *rubriflorum* (J.M.Black) Benl, Mitt. Bot. Staatssamml. München 3: 518 (1960), **syn. nov.**
Type: South Australia. Near Oodnadatta, November 1914, *Staer s.n.*; holo AD.

Ptilotus polystachyus var. *arthrotrichus* Benl, Mitt. Bot. Staatssamml. München 7: 317 (1970); *Ptilotus polystachyus* f. *arthrotrichus* (Benl) Benl, Nuytsia 4: 273 (1983), **syn. nov.**

Type: Western Australia. 6 miles [10 km] N of Roeburne, 17 October 1941, *C.A. Gardner 6323*; holo PERTH, n.v.

Ptilotus polystachyus f. *ruber* Benl, Mitt. Bot. Staatssamml. München 15: 169 (1979), **syn. nov.**
Type: Western Australia. 28 km NE of Shay Gap, 22 July 1977, *I.R. Telford 5985*; holo CANB.

Illustrations: Cunningham et al. (1981: 289); Jacobs & Lapinpuro (1990: 257); Wheeler (1992: 131, t. 34D); Milson, Pl. Ident. in Arid Zone 30 (1995); Walsh (1996: 211, t. 37c–d); Elliot & Jones, Encycl. Australian Pl., Volume 8: 120 (2002); Moore, Guide Pl. Inland Australia 260 (2005).

Distribution and habitat: *P. polystachyus* is perhaps the most widespread of all *Ptilotus* species, occurring in all mainland states and the N.T., its range extending from near Inglewood in Qld to Shark Bay in W.A., and from Kakadu National Park and the Kimberley to north-western Vic. It occupies a wide range of habitats, but is most frequent in sandy or loamy soils of the inland, near sand-dunes or in *Acacia aneura* communities.

Notes: Benl (1983) discussed the variability of this species, and at that time he recognised four varieties and four formae. Most if not all of these varieties and formae are of no taxonomic consequence. For instance, f. *rubriflorus* is characterised by its spikes 'dull purple fading to brownish', but plants with this coloured inflorescence frequently occur in mixture with plants bearing the normal greenish-white spikes. One of the named varieties, *P. polystachyus* var. *longistachyus*, with its short tepals (9–11 mm long) is perhaps worthy of that rank, but it is unclear to me whether it grades into the typical variety south of the Kimberley. A detailed taxonomic and ecological study of *P. polystachyus* would resolve this, but in the meantime, I believe the best course is to adopt a broadly circumscribed species.

Benl (1983) referred to the type specimen at BM as the holotype. The BM specimen comprises only inflorescences with a short section of stem and lacking any leaves. As Gaudichaud described the leaves in the protologue, the description was clearly not based solely on the BM material, and it should be referred to as a syntype.

Ptilotus pseudohelipteroides Benl, Muelleria 1: 105 (1959)

Type: Queensland. Currawilla, c. 100 miles [161 km] west of Windorah, 9 June 1949, *S.L. Everist 3937*; holo CANB; iso BRI.

Benl, Fl. Cent. Austral. 80 (1981); Elliot & Jones, Encycl. Australian Pl., Volume 8: 120 (2002).

Trichinium helipteroides var. *minor* J.M.Black, Fl. S. Austral. 2: 212 (1924) and Trans. & Proc. Roy. Soc. South Australia 48: 254 (1924); *Ptilotus helipteroides* var. *minor* (J.M.Black) H.Eichler, Suppl. Fl. S. Austral. 2: 130 (1965), **syn. nov.**
Type: South Australia. Blood's Creek, N of Oodnadatta, 20 July 1921, *S.A. White 28*; holo AD; iso K, n.v.
Benl, Fl. South Austral. 1: 327 (1986).

Distribution and habitat: *P. pseudohelipteroides* is distributed in far western Qld (Boulia to Thargomindah), south-eastern N.T. and northern S.A. It inhabits flats, gravelly rises and jump-ups.

Notes: a comparison of the types of *P. pseudohelipteroides* and *T. helipteroides* var. *minor* finds them to be virtually identical, and they are clearly part of the same taxon. Benl, when describing *P. pseudohelipteroides*, made no mention of Black's variety.

The type of *T. helipteroides* var. *minor* is mounted with other non-type specimens. Only the material associated with the label "Bloods Creek 20.7.21" belongs to the holotype. A collection made by Cleland from Blood's Creek in January 1927 is not a part of the type.

Ptilotus remotiflorus Benl, Mitt. Bot. Staatssamml. München 12: 355 (1976).

Type: Queensland. 62 miles [100 km] west of Winton on the Boulia road, 19 March 1972, *H. Reeve 81*; holo CANB.

Ptilotus parvifolius var. *laetus* Benl, Mitt. Bot. Staatssamml. München 7: 315 (1970), **syn. nov.**
Type: New South Wales. Tero Creek station, c. 60 miles [96 km] NW of White Cliffs, 6 December 1968, *B. Parker & M. Stanger 112*; holo CANB; iso MEL.
Cunningham et al. (1981: 288); Benl, Fl. South Austral. 1: 330 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 259–60 (1990).

Illustrations: Cunningham et al. (1981: 288); Jacobs & Lapinpuro (1990: 259), both as *P. parvifolius* var. *laetus*

Distribution and habitat: *P. remotiflorus* is distributed in a relatively narrow arc from Winton in Qld to the far north-west corner of N.S.W. It inhabits rocky or gravelly sites, typically the lower slopes of lateritic break-aways.

Note: the type of *P. parvifolius* var. *laetus* Benl matches *P. remotiflorus* in every regard.

Ptilotus royceanus Benl, J. Roy. Soc. Western Australia 53: 1 (1970).

Type: Western Australia. Bungabiddy rockhole, Walter James Range, 5 October 1966, *A.S. George 8314*; holo PERTH, n.v.; iso CANB, MEL.

Benl, Fl. Cent. Austral. 78 (1981); Elliot & Jones, Encycl. Australian Pl., Volume 8: 122 (2002).

Illustration: Benl, J. Roy. Soc. W. Austral. 53: 2–3, t. 1, 2 (1970).

Distribution and habitat: *P. royceanus* has a remarkably disjunct distribution, found in the far east of W.A. (including the type locality), near Alice Springs in the N.T., and in the Idalia N.P. near Blackall in Qld. It grows on skeletal soils on rocky hills and ranges.

Note: the very widely spaced flowers of the type specimen of *P. royceanus* are not a feature of plants found in Queensland, or of other material collected from the type locality.

Ptilotus schwartzii (F.Muell.) Tate, Trans. Proc. & Rep. Roy. Soc. South Australia 12: 82 (1889).

Ptilotus fraseri var. *schwartzii* F.Muell., Proc. Linn. Soc. New South Wales 3: 163 (1888); *Trichinium schwartzii* (F.Muell.) Farmar, Bull. Herb. Boissier, sér. 2, 5; 1087 (1905).

Type: Northern Territory. Near the Macdonnell's Ranges, *W.F. Schwartz s.n.*; holo ?MEL, n.v.

Benl, Fl. Cent. Austral. 82 (1981); Benl, Fl. South Austral. 1: 331 (1986); Elliot & Jones, Encycl. Australian Pl., Volume 8: 122 (2002).

Illustrations: Milson, Pasture Pl. N.W. Qld 12 (2000); Elliot & Jones, Encycl. Australian Pl., Volume 8: 122 (2002); Moore, Guide Pl. Inland Australia 261 (2005).

Distribution and habitat: *P. schwartzii* is a very widespread species, occurring throughout much of semi-arid W.A. and N.T., extending also to far northern S.A. and into Qld as far east as Aramac. It grows on plains, gravelly rises or stony ridges. Soils may be skeletal or relatively deep, often reddish in colour.

Ptilotus seminudus (J.M.Black) J.M.Black, Fl. S. Austral. 2nd edition, 328 (1948).

Trichinium seminudum J.M.Black, Trans. & Proc. Roy. Soc. South Australia 40: 61 (1916).

Type: South Australia. Minnipa, 11 November 1915, *J.M. Black s.n.*; holo AD, n.v.

Cunningham et al. (1981: 289); Benl, Fl. South Austral. 1: 331 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 259 (1990); Walsh, Fl. Victoria 3: 210 (1996); Elliot & Jones, Encycl. Australian Pl., Volume 8: 122 (2002).

Illustrations: Benl (1986: 332); Jacobs & Lapinpuro (1990: 259); Walsh (1996: 211, t. 37k–l)

Distribution and habitat: in eastern Australia, *P. seminudus* is confined to the north-west of Vic., and the adjacent parts of N.S.W. It is common and widespread in southern parts of S.A., and there is reportedly a disjunct occurrence in W.A. near Esperance.

Ptilotus sessilifolius (Lindl.) Benl, Mitt. Bot. Staatssamml. München 29: 500 (1990).

Trichinium sessilifolium Lindl. in T.Mitch., Three Exped. Australia 2: 12 (1838).

Type: New South Wales. "interior of New Holland" [Byrne's Creek, N.S.W.], 24 March 1836, *T.L. Mitchell 23*; holo CGE, digital image at BRI.

Walsh, Fl. Victoria 3: 207–8 (1996); Elliot & Jones, Encycl. Australian Pl., Volume 8: 123 (2002).

Trichinium atriplicifolium Moq. in A.DC., *Prodr.* 13(2): 286 (1849); *T. obovatum* var. *atriplicifolium* (Moq.) Domin, Biblioth. Bot. 89: 80 (1921); *Ptilotus atriplicifolius* (Moq.) Benl, Mitt. Bot. Staatssamml. München 2: 404 (1958); *Ptilotus atriplicifolius* (Moq.) Benl var. *atriplicifolius*, Mitt. Bot. Staatssamml. München 2: 404 (1958).
Type: New South Wales. Interior of eastern New Holland, swampy-plains, 1817, *A. Cunningham s.n.*; lecto G-DC, fide Benl (1958).
Benl, Fl. Cent. Austral. 79 (1981); Cunningham et al. (1981: 285); Benl, Fl. South Austral. 1: 324 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 259 (1990).

Trichinium obovatum var. grandiflorum Benth., Fl. Austral. 5: 221 (1870); *Trichinium incanum var. grandiflorum* (Benth.) J.M.Black, Trans. & Proc. Roy. Soc. South Australia 41: 380 (1917); *Ptilotus obovatus var. grandiflorus* (Benth.) Ewart & O.B.Davies, Fl. N. Territory 100 (1917).
Type: New South Wales. Harrington Plains, 1817, *A. Cunningham s.n.*; lecto BM, fide Benl (1990), n.v.

Trichinium elderi Farmar, Bull. Herb. Boissier, sér. 2, 5: 1089 (1905); *Ptilotus atriplicifolius* var. *elderi* (Farmar) Benl, Mitt. Bot. Staatssamml. München 2: 404 (1958); *Ptilotus*

sessilifolius var. *elderi* (Farmar) Benl, Mitt. Bot. Staatssamml. München 29: 501 (1990), **syn. nov.**
Type: Western Australia. Cavenagh Range, 31 July 1891, *R. Helms s.n.*; holo K, n.v.; iso MEL.

Trichinium incanum var. *intermedium* Ewart in Ewart & Jean White, Proc. Roy. Soc. Victoria 22: 97 (1909).
Type: South Australia. Warrina, May 1891, *R. Helms s.n.*; holo MEL; iso AD (2 sheets).

Ptilotus oblongifolius Gand., Bull. Soc. Bot. France 66: 222 (1919).
Type: New South Wales. Bourke, undated, *J.H. Maiden*; holo LY, *n.v.*, fide McGillivray, *Contr. New South Wales Natl Herb.* 4: 353 (1973).

Illustrations: Cunningham et al. (1981: 285), as *P. atriplicifolius* var. *atriplicifolius*; Jacobs & Lapinpuro (1990: 259), as *P. atriplicifolius* var. *atriplicifolius*; Milson, Pl. Ident. in Arid Zone 30 (1995); Walsh (1996: 211, t. 37a–b); Moore, Guide Pl. Inland Australia 261 (2005).

Distribution and habitat: *P. sessilifolius* occurs in all mainland states and the N.T., in areas receiving less than about 500 mm rainfall per annum. It grows on a variety of habitats, including sand dunes, and gravelly rises with clay-loam soil.

Notes: Benl (1981) distinguished var. *elderi* by its globose spikes "to 4 cm diameter" vs. globose or cylindric, "to 3 cm diameter" for the typical variety; spikes mostly solitary (vs. in ± loose panicles); and leaves "normally 1–1.5 cm wide" (vs. "to 4 cm wide"). These differences are all very vague, and Benl (*loc. cit.*) admitted that "transitional forms [are] not infrequent". In 1977, Benl determined the MEL isotype of *T. elderi* as *P. atriplicifolius* var. *atriplicifolius*, further evidence of the meaninglessness of the variety. I contend that the recognition of varieties within *P. sessilifolius* is unsustainable.

Ptilotus spathulatus (R.Br.) Poir. in Lam., Encycl. Suppl. 4: 620 (1816).

Trichinium spathulatum R.Br., Prodr. 415 (1810).

Type: Tasmania. Derwent River, above the fall, 29 March 1804, *R. Brown [Bennett No. 3051]*; holo BM, n.v.; iso K, n.v.

Bentham, Fl. Austral. 5: 236–7 (1870); Cunningham et al. (1981: 289); Benl, Fl. South Austral. 1: 331 (1986); Jacobs & Lapinpuro, Fl. N.S.W. 1: 258 (1990); Walsh, Fl. Victoria 3: 209–10 (1996); Elliot & Jones, Encycl. Australian Pl., Volume 8: 123 (2002).

Illustrations: Cunningham et al. (1981: 289); Jacobs & Lapinpuro (1990: 258); Walsh (1996: 211, t. 37i–j); Elliot & Jones, Encycl. Australian Pl., Volume 8: 123 (2002); Moore, Guide Pl. Inland Australia 261 (2005).

Distribution and habitat: *P. spathulatus* is a very widespread species in southern Australia in areas of moderate rainfall. In N.S.W. it occurs west of the Great Divide, south from about Dubbo, and it is common in western Vic. and eastern Tas. It is also common in the southern half of S.A. and the wheatbelt and goldfield areas of W.A.

Note: *P. spathulatus* has some small verticillate hairs on the tepals, but they are hard to see (hidden by the longer septate hairs).

Ptilotus spicatus Benth., Fl. Austral. 5: 243 (1870).

Ptilotus spicatus Benth. var. *spicatus*, Fl. Austral. 5: 243 (1870); *Ptilotus spicatus* Benth. subsp. *spicatus*, Mitt. Bot. Staatssamml. München 6: 493 (1967).

Type: Northern Territory. Victoria River, 1855, *F. Mueller s.n.*; holo K [196971]; iso MEL.

Bentham, Fl. Austral. 5: 243 (1870); Benl, Fl. Cent. Austral. 83 (1981); Wheeler, Fl. Kimb. 132 (1992); Elliot & Jones, Encycl. Australian Pl., Volume 8: 123–4 (2002).

Ptilotus spicatus var. *leianthus* Benth., Fl. Austral. 5: 243 (1870); *Ptilotus leianthus* (Benth.) Domin, Biblioth. Bot. 89: 83 (1921); *Ptilotus spicatus* subsp. *leianthus* (Benth.) Benl, Mitt. Bot. Staatssamml. München 6: 493 (1967), **syn. nov.**
Types: Gulf of Carpentaria, *L. Leichhardt*; syn K; Flinders R., Qld, 1869, *T. Sutherland 91*; syn K, MEL; NSW, n.v.; Attack Creek, 1862, *J. McDowall Stuart*; syn K, MEL; Flinders R., Qld, *Bowman*; syn ?K, n.v.; syn MEL.

Ptilotus spicatus subsp. *burbidgeanus* Benl, Mitt. Bot. Staatssamml. München 6: 496 (1967); *Ptilotus spicatus* var. *burbidgeanus* (Benl) Benl, Mitt. Bot. Staatssamml. München 15: 173 (1979), **syn. nov.**
Type: Western Australia. Kimberley Research Stn, Ord R., 26 March 1949, *E.C.B. Langfield 59*; holo CANB.

Ptilotus spicatus subsp. *longiceps* Benl, Mitt. Bot. Staatssamml. München 6: 495 (1967), **syn. nov.**
Type: Northern Territory. Beswick Station, *c.* 4 miles [6 km] E of homestead, 11 April 1962, *D.J. Nelson 257*; holo M, n.v.; iso DNA, n.v., NSW.

Illustrations: Wheeler (1992: 131, t. 34E); Milson, Pl. Ident. in Arid Zone 30 (1995); Milson, Pasture Pl. N.W. Qld 13 (2000).

Distribution and habitat: *P. spicatus* is distributed across tropical Australia from near Derby in W.A. to Hughenden, Qld, mainly away from the coast. It almost extends to the Gulf of Carpentaria, but is absent from the "Top End" of the N.T. It usually inhabits *Astrebla*-dominated grassland on clay soils, but can also be found on stony plains or sandy soils overlying clay.

Note: Benl (1967b) diagnosed the varieties and subspecies of *P. spicatus* on the basis of tepal length, the length of the apiculum on the bracteole, and the hairiness of the ovary. These features do vary, but seemingly at random, uncorrelated to other characters, ecological site or distribution.

Excluded species

Ptilotus fraseri (A.Cunn. ex Moq.) F.Muell., Syst. Census Austral. Pl. suppl. 1, 29 (1884)

Trichinium fraseri A.Cunn. ex Moq. in A.DC., *Prodr.* 13(2): 295 (1849).

Type: interior of New South Wales, *anno* 1827, *C. Fraser s.n.*; iso G-DC, microfiche.

Notes: the label of the type specimen of *T. fraseri* says "*interior of N. S. Wales, 1827, C. Fraser*" in the handwriting of Allan Cunningham. However, it is known that in 1827, Charles Fraser collected specimens only around the Swan River in Western Australia. Furthermore, the type specimen appears to be a depauperate form of either

P. drummondii or *P. schwartzii*, neither of which occurs in areas of New South Wales that were visited by Fraser.

The identity of *P. fraseri* remains uncertain, and hence it is excluded from this synopsis of eastern Australian species.

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A review of *Elmeriobryum* (Hypnaceae)

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Abstract

Elmeriobryum Broth. is taxonomically reviewed. Previously published synonymy is confirmed. However, material from New Guinea, usually referred to as *E. philippinense*, should better be called ***E. wilhelmense*** (E. B. Bartram) W.R.Buck & B.C.Tan, comb. nov.

Introduction

Elmeriobryum was first used by Brotherus (1913) for two Philippine moss species, *E. philippinense* and *E. assimile*. However, because no separate generic description was provided, the genus was not validly published until Brotherus (1925) provided a generic description in *Die natürlichen Pflanzenfamilien*. Shortly after Brotherus' original use of the name, Williams (1914) described a third Philippine species, *E. brotheri*, from one of his own collections. Oddly, the type collections of all three species were gathered at the same locality, Baguio in Benguet Province in northern Luzon. On the isotype of *E. assimile* at NY, R. S. Williams even annotated it as, "Probably not distinct from *G.* [*Gollania*] *philippinensis*." Brotherus (1928) published *E. formosanum* and its var. *minus* from Taiwan, the first record of the genus outside of the Philippines. Finally, Rohrer (1986) described the first New World species of *Elmeriobryum*, based on Central American material that had been misplaced in *Leptohymenium*.

After this flurry of new species descriptions, most subsequent work on the genus focused on reducing the number of species. In Bartram's Mosses of the Philippines (1939), *E. assimile* and *E. brotheri* were reduced to synonymy under *E. philippinense*. Noguchi (1962) added to that synonymy by including *E. formosanum* and *E. formosanum* var. *minus* in the synonymy of *E. philippinense*. However, Noguchi (1962) considered *Elmeriobryum* to be a synonym of *Gollania* and most subsequent Asian workers followed his lead. Subsequently, Rohrer (1985), in a phyletic analysis of the Hylocomiaceae, found that *Gollania philippinensis* was only weakly related to the other species in the genus and suggested that *Elmeriobryum* should be resurrected. Rohrer (1986) also suggested that all Asian names in *Elmeriobryum* represent a single species. Since that time, workers have considered *Elmeriobryum* to be represented in Asia by *E. philippinense* alone.

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However, as time went by and additional collections were made, *Elmeriobryum philippinense* was used not only for material from the Philippines and Taiwan, where almost all collections were made below 2000 m (rarely to 2700 m) and growing on rock (rarely on tree trunks and branches), but also from Papua New Guinea (Koponen & Norris 1985). These New Guinea specimens were mostly collected above 3000 m (rarely down to 2400 m) and almost exclusively on humus and soil, often in marshy areas. The plants are decidedly larger than the Philippine/Taiwan material and there are a number of other microscopic differences as well. This material was described by Bartram (1965) as *Calliergon wilhelmense*. Despite Bartram's experience with *Elmeriobryum* in the Philippines, he never realized the congeneric relationship of his *Calliergon wilhelmense*. Subsequently, Koponen and Norris (1985) synonymized the name with *E. philippinense*, a taxonomic decision with which we disagree. We take this opportunity to make the new combination and review the species of *Elmeriobryum*.

Elmeriobryum Broth. *in* Engler, Die natürlichen Pflanzenfamilien, ed. 2, 11: 204. 1925; Leafl. Philipp. Bot. 6: 1974. 1913, *nom. inval. sine descr. gen.* Type: *E. philippinense* Broth.

Plants relatively robust, ± turgid, in somewhat shiny, golden- to red-brown to yellow-green, extensive mats. *Stems* creeping, irregularly branched, procumbent to ascending; in cross-section without a hyalodermis, with small thick-walled cells surrounding larger thin-walled cells, central strand present; pseudoparaphyllia foliose; axillary hairs consisting of 1(–2) short brown basal cells and 2–3 elongate hyaline distal cells. Stem and branch *leaves* somewhat differentiated, imbricate, erect- to wide-spreading, ovate to oblong, apiculate to short-acuminate, strongly concave, somewhat plicate; margins mostly serrulate above, entire below, plane to incurved; cells linear, smooth or minutely prorulose, thin- to firm-walled; alar cells not or somewhat differentiated. Asexual propagula none. Dioicous. Perichaetia large, leaves oblong, long-acuminate, plicate; margins subentire, plane; costa usually none; cells linear-flexuose, smooth, becoming laxly rectangular toward the insertion; alar cells not differentiated. *Setae* very elongate, smooth, reddish; *capsules* inclined, weakly arcuate, ± asymmetric, oblong; exothecial cells subquadrate to irregularly short-rectangular, firm-walled, not collenchymatous; annulus well differentiated; operculum apiculate; peristome double, exostome teeth yellow-brown, shouldered, bordered, on the front surface with a zig-zag median line, not furrowed, cross-striolate below, coarsely papillose above, trabeculate at back; endostome with a high basal membrane, segments keeled, narrow, perforate, about as long as the teeth, cilia in groups of 1–3, nodose. *Spores* spherical, papillose. *Calyptrae* small-cucullate, naked, smooth.

Key to the species of *Elmeriobryum*

1. Plants robust, turgid, stems erect, 2–3 mm wide with leaves, typically growing on humus or soil, restricted to New Guinea .... 3. ***E. wilhelmense***

1. Plants more slender, weakly turgid, stems creeping, 1–1.5 mm wide with leaves, typically growing on rocks or trees, Asian or Central American 2

2. Plants of Asia; stem leaves weakly plicate, c. 0.5 mm wide; costa of stem leaves 1/5–1/6 the leaf length; alar cells distinctly differentiated .... 1. ***E. philippinense***

2. Plants of Central America; stem leaves distinctly plicate, more than 0.7 mm wide; costa of stem leaves 1/4–1/2 the leaf length; alar cells scarcely differentiated .... 2. ***E. guatemalense***

1. ***Elmeriobryum philippinense*** Broth. *in* Engler, Die natürlichen Pflanzenfamilien, ed. 2, 11: 204. 1925; Leafl. Philipp. Bot. 6: 1974. 1913, *nom. inval.*

Type: Philippines. Luzon: Benguet Prov., Baguio, *Elmer 8374* (H-BR, holotype; NY, isotype).

Elmeriobryum assimile Broth. *in* Engler, Die natürlichen Pflanzenfamilien, ed. 2, 11: 204. 1925; Leafl. Philipp. Bot. 6: 1975. 1913, *nom. inval.*
Type: Philippines. Luzon: Benguet Prov., Baguio, *Elmer 8449* (H-BR, holotype; NY, isotype).

Elmeriobryum brotheri R. S. Williams *ex* Broth. *in* Engler, Die natürlichen Pflanzenfamilien, edn 2, 11: 204. 1925; R. S. Williams, Bull. New York Bot. Gard. 8: 366. 1914, *nom. inval.*; *Ectropothecium brotheri* (Broth.) Higuchi, J. Hattori Bot. Lab. 59: 69. 1985.
Type: Philippines. Northern Luzon: Benguet Prov., Baguio, 1600 m, *Williams 1728* (NY, holotype).

Elmeriobryum formosanum Broth., Ann. Bryol. 1: 21. 1928, *fide* Noguchi, Acta Phytotax. Geobot. 20: 241. 1962.
Type: China. Formosa: Prov. Taityn, Onae, *J. Suzuki* (H-BR, holotype, not seen).

Elmeriobryum formosanum var. *minus* Broth., Ann. Bryol. 1: 21. 1928, *fide* Noguchi, Acta Phytotax. Geobot. 20: 241. 1962.
Type: China. Formosa: Prov. Taityn, Onae, *J. Suzuki* (H-BR, holotype, not seen).

Plants relatively robust, in shiny, golden-brown to yellow-green, extensive, loose mats. *Stems* to c. 10 cm, creeping, elongate, irregularly and distantly 1–2-pinnately branched; in cross-section with 2–3 rows of small thick-walled cells surrounding abruptly larger thin-walled cells, central strand of small thin-walled cells; pseudoparaphyllia broadly foliose; axillary hairs consisting of 1(–2) short brown basal cells and 2–3 elongate mostly pale yellow, rarely hyaline distal cells. Stem and branch *leaves* somewhat differentiated; stem leaves 1.0–1.4 mm long, c. 0.5 mm wide, erect to erect-spreading when dry, spreading when moist, broadly ovate, abruptly tapered to a broadly short-acuminate, recurved, often twisted apex, strongly concave, not plicate; margins serrulate in the acumen, subentire below, plane to narrowly recurved at base, plane or broadly inrolled above; costa double, the two forks separated at base and spreading, extending 1/6–1/5 the leaf length; cells 34–48(–56) × c. 3 µm, narrowly linear, somewhat flexuose, firm-walled, not or weakly porose, smooth, basal cells wider, thicker-walled, porose; alar cells restricted to extreme basal corners, irregularly short-rectangular, thick-walled, concolorous with cells above, in c. 6–7 rows, extending up the margins by 4–5 cells. Branch leaves c. 0.8 mm long, 0.3 mm wide, ovate. Asexual propagula none. Dioicous. Perichaetia large, leaves to 3 mm long, erect, slightly plicate, ecostate; margins entire or minutely serrulate above. *Setae* to 3 cm long, smooth, reddish; *capsules* inclined to horizontal, 2–2.25 mm long, subarcuate, contracted under the mouth when dry and empty; exothecial cells isodiametric to short-rectangular, thin- to firm-walled, becoming small-quadrate to oblate and thick-walled in 3–5 at the mouth; annulus broad, of 2 rows of thick-walled cells, the lower (attached to urn) small, quadrate, the upper (attached to operculum) rectangular, ± inflated; operculum conic-mammillate; exostome teeth on front surface cross-striolate below, coarsely papillose above, trabeculate at back; endostome with a high, smooth basal membrane, segments finely papillose, keeled, narrowly perforate, about as long as the teeth, cilia in pairs, very short. *Spores* 22–25 µm in diameter, papillose. *Calyptrae* cucullate, naked, smooth.

Selected specimens studied: PHILIPPINES. Luzon: Benguet Prov., *Merrill 7825, 7835, 7842, Fénix 12943* (all NY), Baguio and vicinity, *Robinson 11999* (NY), near Baguio, *Williams 1729* (NY), between Baguio and Mt. Santo Tomas, *Williams 1706*; Mountain (=Bontoc) Prov., *Vanoverbergh 598, 1318* (NY), Mt. Sto. Tomas, *Cuevas 6150* (NY), Banguio, near road to airport, *Bartlett 13365* (NY); Bontoc Prov., near Bontoc, 6000 ft, *Mack 1402* (NY); Ifugao Prov., Mt. Polis, *McGregor 20309* (NY). **TAIWAN. Hwalien Co.:** Tzuen, c. 2000 m, *Lai 13532, 13593* (NY). **Ilan Co.:** Chilan, *Lai 12277* (NY). **Nantou Co.:** Chitou, c. 1100 m, *Lai 11571, Lin, Bryophtyes of Taiwan no. 68, Ogasawara et al., Bryophyta Exsiccata no. 116* (all NY).

Distribution and ecology: Philippines, Taiwan; growing at 1200–1900(–2700) m, mostly on rocks but sometimes on tree trunks and branches.

Discussion: *Elmeriobryum philippinense* is a handsome plant, and quite similar in aspect to *E. guatemalense*, and not at all like *E. wilhelmense*. From *E. guatemalense*, it can be separated by smaller leaves with shorter but narrower laminal cells. The costa is distinctly shorter and the alar region is better differentiated. From *E. wilhelmense*, it can be separated by the creeping as opposed to erect stems that are more slender and less turgid, by the narrower stem leaves with a flat apex, and by thinner-walled laminal cells.

One of the synonyms of *E. philippinense*, *E. brotheri*, was transferred to *Ectropothecium* by Higuchi (1985) on the basis of a few gametophytic characters, the most compelling being the “few small cells with a few enlarged hyaline cells at the angle of alar parts of stem-leaves.” However, these basal cells are thick-walled in *Elmeriobryum*, not thin-walled as in *Ectropothecium*. Presumably Higuchi (1985) did not have sporophytes in making his decision. In *Ectropothecium* the capsules are very small, almost spherical, and seldom more than about 1 mm long. Here, the capsules are arcuate-cylindrical and over 2 mm long, readily excluding the plants from *Ectropothecium*.

2. *Elmeriobryum guatemalense* J. R. Rohrer, Bryologist 89: 29. 1986.

Type: Guatemala. San Marcos: Barranco Eminencia, road between San Marcos and San Rafael Pie de la Cuesta, in upper part of the barranco between Finca La Lucha and Buena Vista, 2500–2700 m, 6 Feb 1941, *Standley 86466* (MICH, holotype; F, FH, NY isotypes).

Plants relatively robust, in shiny, golden-brown to yellow-green, extensive, loose mats. *Stems* to ca 10 cm, creeping, elongate, irregularly and distantly 1–2-pinnately branched; in cross-section with 2–3 rows of small thick-walled cells surrounding abruptly larger thin-walled cells, central strand of small very thin-walled cells; pseudoparaphyllia foliose; axillary hairs consisting of 1 short brown basal cell and 2 elongate hyaline distal cells. Stem and branch *leaves* somewhat differentiated; stem leaves 1.0–1.8 mm long, 0.7–1.4 mm wide, erect to erect-spreading when dry, spreading when moist, broadly ovate to oblong, abruptly apiculate, concave, plicate; margins serrulate above, entire below, reflexed at base, plane or broadly inrolled above; costa double, the two forks separated at base and ± parallel, extending 1/4–1/2 the leaf length; cells 25–75 × 4–7 µm, narrowly elliptic to linear, smooth or sometimes minutely prorulose, basal cells wider, porose; alar cells scarcely differentiated, slightly wider than other basal cells. Branch leaves 1.0–1.5 mm long, 0.4–0.7 mm wide, ovate to elliptic, less plicate than stem leaves. Asexual propagula none. Apparently dioicous. Perichaetia and *sporophytes* unknown.

Selected specimens examined: GUATEMALA. Guatemala: Volcán de Pacaya, *Standley 80724* (F, FH, MICH, US). **Quezaltenango:** El Pocito, S of San Martín Chile Verde, *Standley 85043*

(F, MICH, NY). **San Marcos:** Barranco Eminencia, *Standley 68524* (F, FH). **Sololá:** Volcán Atitlán, *Steyermark 47464* (F, FH, MICH, NY, TENN). **EL SALVADOR. Santa Ana:** Cerro Miramundo NW of Metapán, *Carlson 962b* (F, FH). **COSTA RICA. Heredia:** Volcán Barba, *Griffin et al. D-268* (CANM, F, MO, NY).

Distribution and ecology: Guatemala, El Salvador and Costa; growing on tree trunks and branches and moist rocks and roadbanks in cool, moist forests, at 1800–3100 m.

Discussion: this little-known species was formerly confused with *Leptohymenium* (Hylocomiaceae), but was resolved by Rohrer (1986). Unlike *Leptohymenium* and the rest of the Hylocomiaceae, the branching in *Elmeriobryum* is monopodial rather than sympodial, and the leaves are not at all decurrent with the alar cells scarcely if at all differentiated. This New World species differs from its Asian counterpart, *E. philippinense*, by the leaves more strongly plicate, with an apiculate rather than acute apex, and a stronger costa. Also, in *E. guatemalense* the alar cells are more poorly differentiated.

3. *Elmeriobryum wilhelmense* (E. B. Bartram) W. R. Buck & B.C. Tan, ***comb. nov.***

Calliergon wilhelmense E. B. Bartram, Contr. U.S. Natl. Herb. 37(2): 60. 1965.

Type: New Guinea. Eastern Highlands District: Mt. Wilhelm, east slopes, 13,100 ft, coll. *J. D. Collins* (*Brass 29943*) (US, holotype).

Plants robust, in shiny, red- to golden-brown to yellow-green, extensive, loose tufts. *Stems* to c. 5 cm, erect, irregularly and distantly 1-pinnately branched, turgidly foliate; in cross-section with 2–3 rows of small thick-walled cells surrounding abruptly larger thin-walled cells, central strand of small thin-walled cells; pseudoparaphyllia broadly foliose; axillary hairs consisting of 1(–2) short brown basal cells and 2–3 elongate yellowish, rarely hyaline distal cells. Stem and branch *leaves* somewhat differentiated; stem leaves 1.25–2.0 mm long, 0.75–0.9 mm wide, erect to erect-spreading when dry, spreading when moist, broadly ovate, abruptly shortly broad-apiculate, strongly concave, not plicate; margins serrulate in the acumen, subentire below, plane to erect at base, plane or broadly inrolled immediately below apiculus; costa double, the two forks separated at base and spreading, extending 1/5–1/4 the leaf length; cells 48–57 µm long, lumina c. 3 µm broad with walls as thick or thicker than the lumina, narrowly linear, somewhat flexuose, thick-walled, ± porose, smooth, basal cells shorter, wider, thicker-walled, porose; alar cells restricted to extreme basal corners, subquadrate to short-rectangular, thick-walled, concolorous with cells above or dark red, in c. 6–8 rows, extending up the margins by 3–5 cells. Branch leaves 1–1.2 mm long, 0.4–0.65 mm wide, oblong-ovate. Asexual propagula none. Apparently dioicous. Perichaetia and *sporophytes* unknown.

Specimens examined: PAPUA NEW GUINEA. Chimbu Prov.: Massif du mont Wilhelm, rive sud du lac Piunde, 3500 m, *De Sloover 42896, Herbier Bryologique no. 757* (NAM, NY), rive est du lac Piunde, 3500, *De Sloover 42737, Herbier Bryologique no. 708* (NAM, NY). **Morobe Prov.:** Mt. Sarawaket Southern Range 2.5 km S of L. Gwam and E of Mt. Enggum, headwaters of Sankwep R., 6°21'S, 147°07'E, 3500–3570 m, *Koponen 32742* (H, NY), 4 km E of L. Gwam, 6°19'S, 147°09.5'E, 3100–3200 m, *Koponen 32870* (H, NY); Lake Wamba 5 km S of Teptep airstrip, 6°01'S, 146°33'E, 2430 m, *Koponen 33279* (H, NY). **Simbu Prov.:** Kombugomambuno, 4 km SE of Mt. Wilhelm, 5°48'S, 145°08'E, *Mundua 78* (CBG, NY); Lake Aunde, 3 km SE of Mt. Wilhelm, 5°47'S, 145°07'E, 3660 m, *Mundua 108* (CBG, NY). **Southern Highlands Prov.:** Massif du mont Giluwe, entre Karil (15 km au NE de Mendi) et le sommet, 3100 m, *De Sloover 43082* (NAM, NY). **West Sepik Distr.:** Star Mts, Silil'katibin, NW of Mt. Auriga, c. 5°S, 141°05'E, 3500 m, *Touw 16652, 16658* (L, NY); SW of Mt. Capella Base Camp, c. 5°S, 141°05'E, 3400 m, *Touw 16590* (L, NY).

Distribution and ecology: Papua New Guinea endemic; growing on moist soil or humus, often in open, swampy habitats, at (2400–)3100–4000 m.

Discussion: this handsome plant differs from the other two species in its erect growth habit, usually in open, swampy habitats, as opposed to creeping in moist forests. The plants are very turgid and the leaves are broadly ovate. The laminal cells are very thick-walled, with the walls as wide as or wider than the lumina. Like *E. philippinense*, *E. wilhelmense* has reasonably well-developed alar cells. However, the very different habit (and habitat) and the incrassate laminal cells will readily separate it. From an Australian perspective, *E. wilhelmense* recalls the ACT endemic, *Bryostreimannia turgida* (Ochyra) Ochyra, both in terms of the turgid aspect and the swampy habitat. However, that plant is a pale green rather than the often reddish tinge exhibited in *E. wilhelmense*. Additionally, in *B. turgida* the leaves are less concave and more long-acuminate. The most significant differences, though, are in the alar region. In *E. wilhelmense*, the alar cells are few, small, and thick-walled. In *B. turgida*, the alar cells are quite numerous and often have an excavate area of hyaline, inflated, thin-walled cells (not unlike many other Amblystegiaceae). From the North Temperate *Pseudo-calliergon turgescens* (T. Jensen) Loeske (also Amblystegiaceae), *E. wilhelmense* differs by the non-calcareous habitat, broader leaves, larger alar cells and non-porose upper laminal cells.

Acknowledgments

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Doodia hindii (Blechnaceae) a new species from north eastern New South Wales, Australia

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Abstract

Doodia hindii Tindale ex T.C.Chambers is described for the first time. This is a rarely collected species from rainforest in mountain regions of north eastern New South Wales, bringing to nine the number of species of *Doodia* in Australia .

Introduction

The genus *Doodia* (Blechnaceae) is estimated to contain more than 30 species distributed through Australasia, Papuasia, Malesia, Sri Lanka and the Pacific region extending north east to Hawaii and as far east as Easter Island (Parris 1972, 1998). Hybrids have been reported among some of the species especially in the *D. caudata* complex (Andrews 1990). Eight species have been defined by Parris (1998) in the *Flora of Australia* treatment. By modifying the key provided there, this additional (ninth) Australian taxon can be accommodated as follows (modifications are in italics):

4: Numerous strongly reduced basal pinnae/*segments* present; abaxial surface of pinnae/*segments* mid vein either *with or without* tubercles 5

  5 Rhizome erect, forming *caudex* up to 30 cm .... **1. *D. maxima***

  5: Rhizome short to long creeping; *tubercles present on stipe* .... **5. *D. australis***

  5a Rhizome short (but may develop an erect caudex); stipe glabrous, dark at the base, usually stramineous at least on the adaxial surface, smooth, shiny, and without tubercles.......... **9. *D. hindii***

Taxonomy

Doodia hindii Tindale ex T.C.Chambers ***sp. nov.,*** **Fig. 1 a–d**

Rhizoma caespitosum vel breve repens; caudex 1.5 cm diametro usque ad 16 cm elatus; frons 40(–50) cm longa aut pendens aut patens frondibus maturis plerumque fertilibus; stipes laevigatus glaber, adaxialiter aureus vel stramineus, abaxialiter purpureus apicem versus rhachidis gradatim lutescens.

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Fig 1. *Doodia hindii.* **a,** habit of plant growing in soil in a flat area. **b,** typical scale from the base of the stipe. **c,** abaxial surface of the apical half of a segment showing detail of venation, and sporangia. **d,** abaxial surface of mature frond (a,b from living collections at the Fernery at RBG Sydney c, d from *Coveny 10555 & Hind*). Scale bar: a = 15 cm; b = 2.5 mm; c = 7.5 mm; d = 7.5 cm.

Type: New South Wales: North Coast: Eden Creek Falls, Toonumbar State Forest, 20 km NW of Kyogle, near the Queensland border, locally common on steep slopes in rain forest near falls with *Pellaea nana, Lastreopsis munita, Adiantum spp.* 28°30'S 152°48'E, *R. Coveny 10555* & *P. Hind*, 25.12.1979; holotype: NSW 507718; isotypes: MEL, CANB, ABRI, & AK.

Rhizome short creeping, tufted erect to sub-erect, *caudex* 1.0–1.5 cm diameter; and up to 15 cm in height in older plants (in cultivation) supporting a crown of arching or pendulous fronds 20–40 (–50) cm long, often pendulous (in specimens growing on steep banks) but distinctly flat and spreading for plants established on level soil areas; *stipes* smooth (no tubercles), deeply grooved on the adaxial surface, 9–15 (–20) cm long with basal scales persistent, lustrous black to matte dark red-brown, long-acuminate, essentially entire, (sometimes with an occasional minute marginal outgrowth); stipes black at the base becoming paler and stramineous in most specimens towards the rhachis, usually much shorter than the lamina and with a deep groove adaxially; *rhachis* with a conspicuous deep single groove on the adaxial face extending for its full length; and adaxially the rhachis on most specimens pale stramineous and shiny; in larger plants the dark pigmentation of the stipe extending up the smooth, abaxial surface grading to stramineous towards the apex; *lamina* rich olive to dark green adaxially, linear-lanceolate, pinnate and with a variable number of usually contiguous reduced photosynthetic adnate segments (auricles) towards the lamina base; in some plants there is a single larger pair of sessile very shortly stalked pinnae; all segments including the auricles (and pinnae at the lamina base if present) usually fertile; auricles with 1–3 sori, the fully developed segments with 5–15 sori per single row each side of the costa, each sorus attached to a commissural vein on the side facing the costa; *indusium* single thin, papery, pale-brown to fawn-coloured, entire, arising on the side of the vein nearest to the segment margin; *segments* lanceolate in outline, 3–5 mm wide 1–3 (–5) cm long, the apices varying from acuminate to somewhat attenuate with margins distinctly dentate; venation typical for the genus, more conspicuous on the paler abaxial surface, and with each commissural vein supporting a sorus and usually with two vein branches each terminating at a separate marginal tooth arising from the slightly thickened segment margin; *terminal segment* longer than the lateral segments, 4–6 cm long and up to 8 mm wide at its base, caudate, acuminate, and usually fertile.

Spores: 64 per sporangium, (this count was made by P. Kodela for Dr M. Tindale).

Chromosomes: under *Doodia sp* Wiangaree SF, NSW, *P. Hind 2750* (NSW) and Wiangaree *P.D, Hind 2568*, Tindale and Roy (2002) report 2n = 64 (diploid); see their fig.142, photomicrograph illustrating n = 32 bivalents.

Distribution and habitat: known only from four sites in open forest and rainforest in mountainous areas in north eastern New South Wales one close to the border of Queensland. Collectors have noted that there were other species of ferns also present including *Macrothelypteris torresiana*, *Doodia media* [= *D. australis*], *D. aspera*, *D. caudata* and *D. linearis.* Specimens of *Doodia hindii* are also reported from earth banks above a stream, on steep slopes under rainforest and from open areas near waterfalls (in this latter locality associated with *Pellaea nana, Lastreopsis munita* and *Adiantum spp.*).

Specimens studied: New South Wales: North Coast: Logan Creek, Mount Kripps, Wiangaree State Forest, (Lions Road) near waterfall on earthy banks of stream, locally common, 28°21'S, 152°57'E, *Hind 2570* & *Coveny*, Dec 1979 (NSW428416, AK, BRI, K); Palm Gully a tributary of

Long Creek on steep earth banks, NE of Wiangaree in Wiangaree State Forest, 28°23'S 152°55'E, *Hind 2568* & *Coveny*, living collection No 800022 RBG Sydney, (NSW428578); Eden Creek Falls 20 km NW of Kyogle, Toonumbar State Forest, 28°23'S 152°48'E, locally common on steep slopes in rain forest near falls with *Pellaea falcata* var. *nana, Lastreopsis munita, Adiantum spp., Coveny 10555 & Hind,* Dec 1979 (NSW507718, BRI, BM, CBG, E, K, US); Mt Warning National Park, 9 miles (14.5 km) SW of Murwillumbah, on cliff faces with *Bulbine, Cyperus, Plectranthus, Nephrolepis,* etc., 28°24'S 153°16'E, *Coveny 4528* & *Rodd,* Sep 1972 (NSW245336).

Conservation Status: currently *Doodia hindii* is only recorded from a very limited part of far north-eastern NSW in relatively inaccessible, rugged forested, mountainous areas. Unless further discoveries are made in the adjoining southern Queensland national parks or other conserved areas, *D. hindii* must be regarded as a vulnerable species. Threats to this species would be from uncontrolled bushfires and clearance for road construction and/or forestry activities.

Notes: 1. *Doodia australis* (Parris) Parris is possibly the species most closely related to *D. media* and was originally described from New Zealand material as a sub-species of *D. media.* In the *Flora of Australia* 48: 710 (1998), Parris made the decision to separate *D. australis* from *D. media* and its associated *D. caudata* complex and in doing so recognised *D. australis* as a much more widespread taxon from Australia, in eastern Qld south of latitude c.25° and in eastern N.S.W. Vic. and Tasmania as well as New Zealand, Lord Howe Is.and Norfolk Is.

2. One immature collection of *Doodia* from McPherson Range in south eastern Queensland may possibly belong to *D. hindii* (NSW507717). However basal relatively long segments and very fine stipes suggest either a hybrid origin or if further specimens over a wider geographic area are discovered possibly a separate taxon.

3. Almost certainly additional collecting in north-eastern New South Wales and south-eastern Queensland will lead to extending our knowledge of *Doodia hindii* and of other taxa in this genus.

Acknowledgments

Dr Mary Tindale, some years ago recognised that the above collections represented a distinct and probably undescribed taxon giving these the provisional specific name ‘hindii’ and she has agreed to my preparing a description for publication. We thank Mr Peter Hind and Mr Bob Coveny, Technical Officers, National Herbarium of NSW, for their careful collections and observations and their helpful comments, Lesley Elkin for the skilled drawings to illustrate the morphology of *D. hindii*, Dr Peter Wilson for advice on the Latin diagnosis and general advice on the manuscript, Dr Philip Kodela who had provided the spore count on herbarium material when Dr Tindale was first investigating this species and Dr Tim Entwisle Executive Director (Gardens Trust) for providing facilities for this study.

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New *Pertusaria* (lichenized Ascomycota) from Australia and Thailand

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Abstract

Pertusaria alloluteola*, *P. flavopunctata*, *P. georgeana var. ***victoriana*, *P. glomelliferica*, *P. roseola*** and ***P. variabilis*** from Australia, ***P. allomicrostoma*** and ***P. phusoidaoensis***, from Thailand, and ***P. confluentica***, from Australia and Thailand, are described as new to science. 2'-*O*-methylanziaic acid, methyl 2'-*O*-methylmicrophyllinate and thuringione [2,4,5-trichloro-3-*O*-methylnorlichexanthone] are reported for the first time in the genus *Pertusaria*.

Introduction

Pertusaria DC. is a genus of more than 300 species (Kirk et al. 2001), well-represented on all the continents of the world including Antarctica. Species of *Pertusaria* colonise bark, wood, rock or soil, or may overgrow bryophytes and other small plants. The genus has a diverse chemical composition that underpins the delimitation of many taxa (e.g., see Hanko 1983, Archer 1993). Generic delimitation has been explored by Schmitz et al. (1994).

A recent account of the lichen genus *Pertusaria* in Australia (Archer 1997) listed a total of 128 species and an additional six taxa have since been described (Archer & Elix 2005, Elix & Archer 2007a, Elix & Archer 2007b). Recent examination of further Australian specimens has revealed a further seven new taxa, viz. *Pertusaria alloluteola, P. confluentica, P. flavopunctata, P. georgeana* var. *victoriana, P. glomelliferica, P. roseola* and *P. variabilis. Pertusaria confluentica* has been found to also occur in Thailand, and, in addition, a further two new species have been found in that country, viz. *P. allomicrostoma* and *P. phusoidaoensis.* These specimens were collected during a study of the taxonomy and ecology of the family Pertusariaceae in Thailand (Jariangprasert 2005).

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Materials and Methods

The morphology of the lichen specimens was examined using a Zeiss Stemi 2000C stereomicroscope, and the anatomy, conidia and ascospores were studied using a Zeiss Axiolab compound microscope. Hand sections and squash preparations were examined in water and in 10% KOH; asci were also examined in Lugol's iodine. The chemical constituents were identified by thin-layer chromatography (Culberson 1972, Culberson & Johnson 1982, Elix & Ernst-Russell 1993), high-performance liquid chromatography (Elix et al. 2003) and comparison with authentic samples.

The Species

Pertusaria alloluteola A.W.Archer & Elix, ***sp.nov.*** **Fig. 1**

Pertusariae trimerae (Müll.Arg.) A.W.Archer similis, a qua differt ascis bisporis.

Type: Australia, New South Wales: Goonoo State Forest, Mogriguy Forest Road, 5 km E of Mogriguy, 23 km NNE of Dubbo, 32°04'16"S, 148°42'53"E, alt. 330 m, on *Melaleuca* in *Eucalyptus-Callitris* woodland with *Calytrix* and *Westringea* understorey, *J.A. Elix 36773,* 11 Oct 2005; holotype: CANB.

Thallus pale yellow-green, thin, cracked, surface smooth and dull, corticolous. Apothecia verruciform, conspicuous, scattered, concolorous with the thallus, flattened hemispherical, not constricted at the base, 0.5–0.8 mm diam. Ostioles black, conspicuous, often 1 per verruca but sometimes up to 5 per verruca. Asci amyloid with a distinctive ocular chamber; hymenium non-amyloid. Ascospores 2 per ascus, ellipsoid, smooth, 95–118 µm long, 35–40 µm wide.

Chemistry: thiophaninic acid (minor), 2-chloro-6-*O*-methylnorlichexanthone (trace), 4-chloro-6-*O*-methylnorlichexanthone (trace) and norstictic acid (major).

Specimens examined: Australia: Western Australia: Gwambygine Nature Reserve, 11 km S of York, 31°58'24"S, 116°48'38"E, alt. 245 m, on *Allocasuarina, J.A. Elix 37413,* 4 Apr 2006 (CANB); *ibid.*, on *Melaleuca, J.A. Elix 31736,* 22. Apr 2004 (CANB); Kendenup [c. 7 km NNW of Albany], on fig tree, *R.F. Allen 10,* Nov 1971 (PERTH).

Pertusaria alloluteola is characterised by the yellow thallus, black ostioles, asci with 2 ascospores and the presence of thiophaninic acid and norstictic acid. It is distinguished from the somewhat similar *P. trimera* by the two-spored asci, whereas *P. trimera* has 3- or 4-spored asci. The new species resembles the chemically similar, two spored *P. luteola* Boqueras, described from Spain (Boqueras & Llimona 2003) but can be distinguished from that species by the larger ascospores (95–118 × 35–40 µm vs. 70–95 × 25–35 µm) and the conspicuous ostioles.

Pertusaria allomicrostoma Jariangpr. ***sp. nov.*** **Fig. 2**

Pertusariae microstomae var. *isidiatae* Jariangprasert similis, a qua lichexanthonen continentib et acidum 2'-*O*-methylperlatolicum deficienti differt.

Type: Thailand: Tak Province, Mueang District, Tambon Mae To, Lan Sang National Park, between Tak Province and Mae Sod District, on the way to Musoe Dam and Musoe Lhueang Agricultural Station, on *Knema linifolia,* 970 m, *S. Jariangprasert 3917,* 20 Nov 2002; holotype: QBG.

Thallus greyish green, surface slightly rough, corticolous; isidiate, soredia absent. Isidia concolorous with the thallus, initially globose to branched, appearing moniliform, 0.15–0.2 mm diam., 0.4–0.7 mm long. Apothecia verruciform, conspicuous, slightly flattened above to concave, sometimes constricted at the base, sometimes confluent, 1–3 apothecia per verruca, 0.5–1.1 mm diam. Ostioles black, conspicuous, centrally depressed, not fused, 1–3 per apothecia. Asci amyloid with a distinctive ocular chamber; hymenium non-amyloid. Ascospores (1–)2 per ascus, ellipsoid, smooth, 110–190 µm long, 30–52 µm wide.

Chemistry: lichexanthone (major), stictic acid (major), constictic acid (minor), skyrin (minor), norstictic acid (trace), cryptostictic acid (trace), methyl stictic acid (trace), peristictic acid (trace).

Pertusaria allomicrostoma is characterized by the verruciform apothecia and the isidiate thallus, asci with two smooth ascospores per ascus and its chemistry. The chemistry and the amyloid asci place the species in *Pertusaria* s.str. (*sensu* Schmitt & Lumbsch 2004). There are few fertile isidiate *Pertusaria* species with two ascospores per ascus. *Pertusaria microstoma* var. *isidiata* Jariangprasert, from Thailand, has black ostioles and an isidiate thallus but differs from *P. allomicrostoma* in ascospores and chemistry. Thus *P. microstoma* var. *isidiata* has two rough ascospores and contains 4,5-dichlorolichexanthone and 2'-*O*-methylperlatolic acid (Jariangprasert 2006). The Australian species, *P. isidiosa* A.W. Archer (Archer 1991), also has two smooth ascospores and contains lichexanthone and stictic acid but differs in having pale inconspicuous ostioles and in containing 2'-*O*-methylperlatolic acid as an additional secondary metabolite. At present the new species is only known from the type locality in Tak Province in northern Thailand.

Pertusaria confluentica Jariangpr. & Elix, ***sp. nov.*** **Fig. 3**

Pertusariae scaberulae A.W. Archer similis, a qua acidum confluenticum continenti differt. Apothecia ignota.

Type: Australia: Queensland: Mossman–Mt. Molloy Road, 1 km S of Lions Lookout, 20 km N of Mt. Molloy, 16°32'05"S, 145°22'59"E, alt. 390 m, margins of rainforest, on canopy of roadside tree, *J.A. Elix 36883*, 4 Aug 2006; holotype: BRI.

Thallus pale olive-green, surface somewhat roughened, dull, corticolous, sorediate, lacking isidia. Soralia white, conspicuous, sessile, flattened, 0.8–1.5 mm diam. Apothecia unknown.

Chemistry: lichexanthone (major), confluentic acid (major), ± 2'-*O*-methylmicrophyllinic acid, ± two unknowns (minor).

Specimens examined: Australia: Queensland, type locality, *J.A. Elix 36902, 36904*, 4 Aug 2006 (CANB); Girringun National Park, Stoney Creek, above Wallaman Falls, 51 km W of Ingham, 18°35'54"S, 145°47'51"E, alt. 545 m, on dead tree, *J.A. Elix 38112, 38115*, 25 Jul 2006 (CANB). **Thailand: Loei Province:** Phu Lhuang Wildlife Sanctuary, alt. 1460 m, *S. Jariangprasert 2200*, 3 Feb 2002 (QBG); *ibid.*, *S. Jariangprasert 2265* (RAMK).

Pertusaria confluentica is characterised by the sorediate thallus, the absence of apothecia and the presence of lichexanthone and confluentic acid. Confluentic acid is not known from any other sorediate species of *Pertusaria* but is known from several fertile, corticolous species including *P. ewersii* A.W. Archer & Elix (from Australia), *P. cinchonae* Müll. Arg. (from India), *P. nana* Müll. Arg. (from Argentina), *P. sublaeviganda* Vain.

(from Japan), *P. inthanonensis* Jariangpr. (from Thailand) and *P. weberi* A.W. Archer & Elix (from Papua New Guinea).

Confluentic acid is reported to be a character unique to *Pertusaria s. str.* (Schmitt & Lumbsch 2004). The new species occurs in rainforest in northern Australia (Queensland), and also in Thailand (Loei Province) where it grows on *Persea* and *Acronychia*, and from where it was first reported (S. Jariangprasert 2004, *in litt.*).

Pertusaria flavopunctata A.W.Archer & Elix, ***sp. nov.*** **Fig. 4**

Pertusariae scaberulae A.W.Archer similis, a qua sorediis flavis et arthothelin et thuringionen continenti differt. Apothecia ignota.

Type: Australia: New South Wales: Washpool National Park, Gibraltar Range, Hakea Walk, 78 km E of Glen Innes, 29°28'10"S, 152°21'01"E, alt. 895 m, on dead tree in mixed rainforest with scattered *Eucalyptus*, *J.A. Elix 37278*, 2 May 2005; holotype: CANB.

Thallus pale yellow-green, surface scurfy and cracked, corticolous. Isidia lacking, sorediate, soralia conspicuous, sessile or slightly raised, scattered, composed of bright yellow to yellow-green soredia, 0.5–1.0 mm diam. Apothecia unknown.

Chemistry: arthothelin (major), thuringione (major), 3-*O*-methylthiophanic acid (minor), and 4,5-dichloronorlichexanthone (trace).

Specimens examined: Australia: Queensland: Paluma Rainforest Walk, Paluma, 19°00'27"S, 146°12'24"E, alt. 830 m, on tree trunk, *J.A. Elix 37590*, 24 Jul 2006 (CANB). **New South Wales:** Tomaga River Estuary, 15 km SE of Batemans Bay, 35°49'25"S, 150°10'47"E, alt. 1 m, on *Casuarina*, *J.A. Elix 23337*, 29 Nov 1989 (CANB).

This species is characterised by the conspicuous yellow-green soralia and the presence of arthothelin and thuringione [2,4,5-trichloro-3-*O*-methylnorlichexanthone] as major compounds. Arthothelin occurs in other *Pertusaria* species, including *P. oblongata* Müll. Arg. from Brazil, *P. melanospora* Nyl. from Chile and *P. bartlettii* A.W. Archer & Elix from New Zealand, but *P. flavopunctata* is the first *Pertusaria* species found to contain thuringione as a major compound. The compound was first isolated from *Lecidea carpathica* (Körb.) Szatala (Huneck & Santesson 1969).

Pertusaria georgeana var. ***victoriana*** Elix & A.W.Archer, ***var. nov.*** **Fig. 5**

Pertusariae georgeanae A.W.Archer & Elix affinis a qua acidum planaicum continenti differt. Apothecia ignota.

Type: Australia: Victoria: Reef Hills State Park, 7 km SSW of Benalla, 36°36'53"S, 145°56'03"E, alt. 155 m, on dead stump in open *Eucalyptus* woodland, *J.A. Elix 36957*, 5 May 2006; holotype: CANB; isotype: MEL.

Thallus off-white to greenish-white, surface smooth and dull, corticolous. Lacking soredia, isidiate, isidia inconspicuous, numerous, concolorous with the thallus, simple, rarely branched, 0.1–0.2 mm tall, 0.05 mm diam. Apothecia unknown.

Chemistry: 4,5-dichlorolichexanthone (minor) and planaic acid (major).

Specimens examined: Australia: Victoria: Chiltern-Mt. Pilot National Park, 2 km N of Chiltern, 36°07'47"S, 146°36'42"E, alt, 200 m, on dead wood in open *Eucalyptus* woodland, *J.A. Elix 36923, 36927, 36957*, 5 May 2006 (CANB).

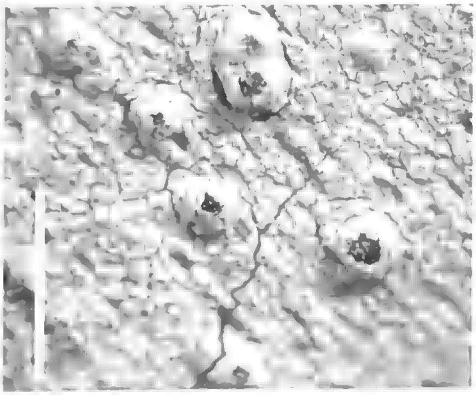

Fig. 1.

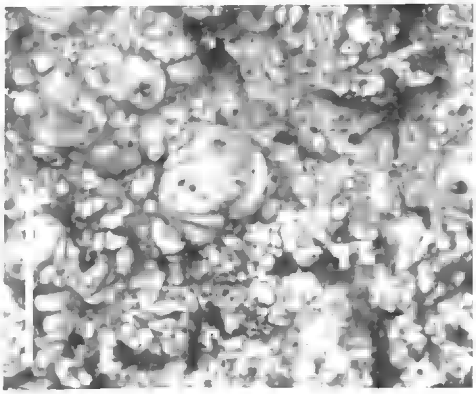

Fig. 2.

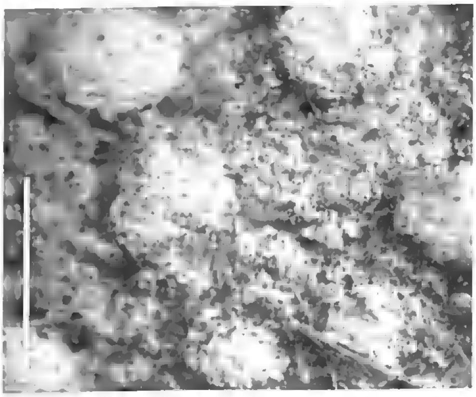

Fig. 3.

Fig. 4.

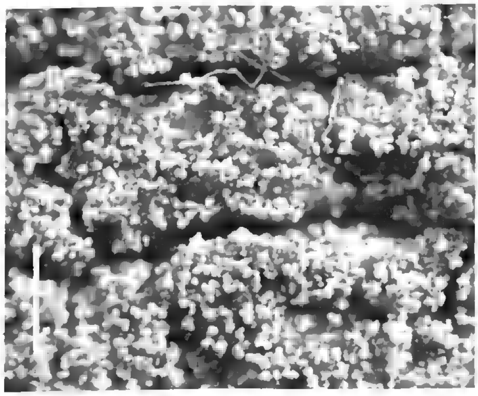

Fig. 5.

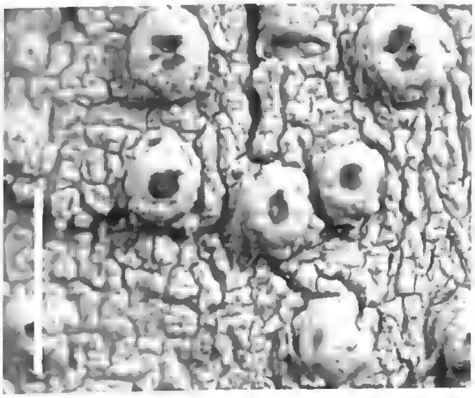

Fig. 6.

Fig. 1. *Pertusaria alloluteola*, holotype. Scale bar = 2 mm. **Fig. 2.** *Pertusaria allomicrostoma*, holotype. Scale bar = 2 mm. **Fig. 3.** *Pertusaria confluentica*, holotype. Scale bar = 1 mm. **Fig. 4.** *Pertusaria flavopunctata*, holotype. Scale bar = 1 mm. **Fig. 5.** *Pertusaria georgeana* var. *victoriana*, holotype. Scale bar = 1 mm. **Fig. 6.** *Pertusaria glomelliferica*, holotype. Scale bar = 2 mm.

Pertusaria georgeana var. *victoriana* is characterised by the isidiate thallus and the presence of 4,5-dichlorolichexanthone and planaic acid. The planaic acid distinguishes the taxon from var. *goonooensis* Elix & A.W. Archer (Elix & Archer 2007b), which contains the rare depside 2,4-di-*O*-methylolivetoric acid, and var. *georgeana*, which contains 2-*O*-methylperlatolic acid (Archer 1997). At present the new variety is known only from a limited area in Victoria.

Pertusaria glomelliferica Elix & A.W.Archer, ***sp. nov.*** **Fig. 6**

Pertusariae thiospodae Knight similis a qua acidum glomelliferícum continenti differt.

Type: Australia, Western Australia: Burma Road, 29 km SE of junction with Walkaway-Nangetty Road, 29°04'07"S, 115°09'26"E, alt. 240 m, on *Melaleuca* in roadside heath with *Melaleuca* among laterite outcrops, *J.A. Elix 33773*, 4 May 2004; holotype: PERTH.

Thallus pale yellow to yellow, surface smooth and dull, corticolous, isidia and soredia absent. Apothecia verruciform, concolorous with the thallus, conspicuous, numerous, scattered or crowded, sometimes confluent, hemispherical to flattened hemispherical, not constricted at the base, 0.5–0.75(–1.0) mm diam. Ostioles black, punctiform, 0.1–0.2 mm diam., 1(–4) per verruca, sometimes in a pale yellow translucent zone. Asci amyloid with a distinctive ocular chamber; hymenium non-amyloid. Ascospores elongate ellipsoid, hyaline, smooth, 3 (sometimes 2) per ascus, 80–105(120) μm long, (25–)30–36(–40) μm wide.

Chemistry: thiophaninic acid (major), 2-chloro-6-*O*-methylnorlichexanthone (minor), 4-chloro-6-*O*-methylnorlichexanthone (minor), glomelliferic acid (major-minor), ± 4-*O*-demethylgomelliferic acid, ± glomellic acid (minor).

Specimens examined: Australia: Western Australia: Coolimba–Eneabba Road, Nature Reserve, 20 km by road W of Enneaba, 29°52'30"S, 115°05'41"E. alt. 70 m, on dead *Acacia* in *Eucalyptus* woodland with *Melaleuca*, *Patersonia*, *Acacia* and limestone rocks, *J.A. Elix 28904*, 5 May 2004 (CANB); Ellendale Pool, 23 km W of Walkaway, 28°51'38"S, 114°58'25"E, alt. 100 m, on *Acacia* in *Dryandra*, *Eucalyptus*, *Acacia* woodland beside river, *J.A. Elix 33761*, 4 May 2004 (CANB); type locality, *J.A. Elix 33767*, 4 May 2004 (CANB); Wabeling, Quarrell Range, Moora–New Norcia Road, 22 km by road S of Moora, 30°41'S, 116°12'20"E, alt. 275 m, *J.A. Elix 37563B*, 2 Apr 2006 (CANB); Kalbarri National Park, along road to The Loop and Z-bend, 24 km NW of Kalbarri township, 27°37'13"S, 114°23'13"E, alt. 210 m, on *Melaleuca*, *J.A. Elix 33650*, 2 May 2004 (CANB).

Pertusaria glomelliferica is characterised by the yellow thallus and ostioles, asci with 2 or 3 ascospores and the presence of glomelliferic acid. This compound was first isolated from *Parmelia glomellifera* (Nyl.) Nyl. [*Xanthoparmelia verruculifera* (Nyl.) O. Blanco, A. Crespo, Elix, D. Hawksw. & Lumbsch] by Zopf in 1899 (Culberson 1969). It is very common in brown *Xanthoparmelia* (Vain.) Hale species (formerly *Neofuscelia* Essl.) (Esslinger 1977, Elix 1994) but has previously been found in only one species of *Pertusaria* namely, *P. corrugata* Kremp. from Brazil (K. Kalb *in litt.*), where co-metabolites included perlatolic acid and stenosporic acid, but xanthones (e.g. thiophaninic acid) were absent. Glomelliferic acid is closely related to perlatolic acid which, with its derivatives, is common in the genus *Pertusaria*.

Pertusaria phusoidaoensis Jariangpr., ***sp. nov.*** **Fig. 7**

Pertusariae meeanae A.W. Archer & Elix similis a qua acidum 2'-*O*- methylanziaicum continenti differt.

Type: Thailand, Uttaradit Province, Nam Paad District, Baan Huay Muun, Phusoidao National Park, 500 m alt. on dry trunk without bark, *S. Jariangprasert 3925,* 27 Nov 2002; holotype: QBG.

Thallus lignicolous and corticolous, dark green, surface rough, subtuberculate, isidia and soredia absent. Apothecia verruciform, conspicuous, flattened hemispherical and contorted, constricted at the base, confluent, 1–3 apothecia per verruca, 0.5–1.5 mm diam. Ostioles black, conspicuous, sunken, sometimes fused and surrounded with yellow tissue, 1–5 per apothecia. Asci amyloid with a distinctive ocular chamber; hymenium non-amyloid. Ascospores 2(3) per ascus, ellipsoid, smooth, 84–146 µm long, 40–56 µm wide.

Chemistry: K ± yellow, C+ rose red, KC+ rose red, Pd-, UV+ reddish orange; 4,5-dichlorolichexanthone (minor), 2'-*O*-methylanziaic acid (major), ± anziaic acid (trace).

Specimens examined: Thailand: Uttaradit Province: type locality, *S. Jariangprasert 3966*, 27 Nov 2002 (QBG); *ibid. S. Jariangprasert 4003* (RAMK).

Pertusaria phusoidaoensis is characterised by asci with 2 or 3 smooth ascospores and the presence of 4,5-dichlorolichexanthone and 2'-*O*-methylanziaic acid. This depside has not previously been reported in the genus *Pertusaria* and is responsible for the C+ and KC+ rose red colours produced with C and KC. 2'-*O*-methylanziaic acid was previously reported in the genera *Cryptothecia, Lecidea* and *Hypotrachyna* (Lücking et al. 2006) but *P. phusoidaoensis* is the first *Pertusaria* species reported to contain this depside. The new species is morphologically similar to *P. meeana* but differs chemically; *P. meeana* contains 4,5-dichlorolichexanthone and 2-*O*-methylperlatolic acid as major compounds (Archer 1997). The new species grows on the dry trunks and bark of *Shorea* in dry dipterocarp forest, on the way to Huay Tawn pass, in northern Thailand.

Pertusaria roseola A.W.Archer & Elix, ***sp. nov.*** **Fig. 8**

Pertusariae erythrellae Müll. Arg. similis a qua thallis isidiatis differt. Apothecia ignota.

Type: Australia: New South Wales, Mann River Nature Reserve, Diehard Creek, 50 km E of Glenn Innes, 29°40'29"S, 152°05'19"E, alt. 595 m; on vine in *Allocasuarina-Eucalyptus* woodland along stream, *J.A. Elix 37038*, 1 May 2005; holotype: CANB.

Thallus pale pink to pale orange, surface smooth and dull, corticolous, isidiate, lacking soralia. Isidia simple, 0.1–0.25 mm tall, 0.05 mm diam., almost completely covering the thallus. Apothecia unknown.

Chemistry: norstictic acid (major) and connorstictic acid (minor-trace)

Specimens examined: Australia: New South Wales: type locality, 1 May 2005, *J.A. Elix 37038* (CANB); Washpool National Park, Gibraltar Range, Hakea Walk, 78 km E of Glenn Innes, 29°28'10"S, 152°21'01", alt. 895 m, on dead tree, *J.A. Elix 37276*, 2 May 2005 (CANB); *ibid. J.A. Elix 37287*, 2 May 2005 (CANB).

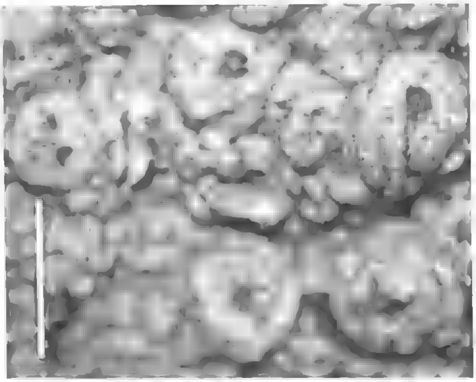

Fig. 7.

Fig. 8.

Fig. 7. *Pertusaria phusoidaoensis*, holotype. Scale bar = 1 mm. **Fig. 8.** *Pertusaria roseola*, holotype. Scale bar = 1 mm.

Pertusaria roseola is characterised by the isidiate thallus and the presence of norstictic acid and differs from the chemically similar *P. erythrella* Müll. Arg. by the presence of isidia in place of soralia. It is distinguished from the chemically similar *P. ramulifera* H. Magn., from Hawaii (Magnusson & Zahlbruckner 1944), by the shorter, predominantly simple isidia, in contrast to the longer, thicker isidia (0.3–0.5 mm wide, to 3 mm long) present in *P. ramulifera*. The two species might be conspecific and the difference in morphology possibly due to environmental differences. In the absence of any intermediate forms the two species are retained here.

Pertusaria variabilis Elix & A.W.Archer, ***sp. nov.*** **Fig. 9**

Pertusariae scaberulae A.W.Archer similis a qua sorediis inconspicuis et methyl 2'-*O*-methymicrophyllinaten continenti differt. Apothecia ignota.

Type: Australia: Northern Territory, Kakadu National Park, Gungarre Forest Walk, South Alligator, 12°40'36"S, 132°28'44"E, alt. 30 m, on dead branches in lowland

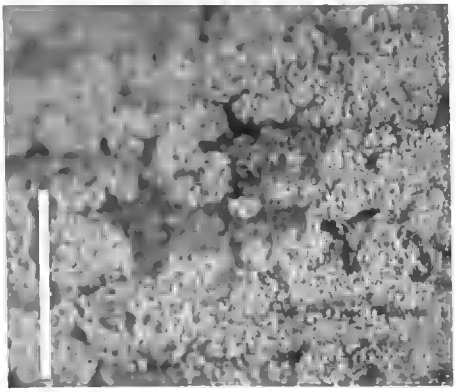

Fig. 9.

Fig. 9. *Pertusaria variabilis*, holotype. Scale bar = 1 mm.

rainforest, *J.A. Elix 37897*, 10 Aug 2005; holotype CANB.

Thallus white, surface smooth and dull, corticolous, isidia lacking, sorediate. Soralia flattened, inconspicuous, white to off-white, scattered to sometimes confluent, 0.2–0.5 mm diam. Apothecia unknown.

Chemistry: methyl 2'-*O*-methylmicrophyllinate (major), ± lichexanthone (major), ± psoromic acid (minor).

Specimens examined: Australia: Northern Territory:, type locality, *J.A. Elix 37870, 37876*, 10 Aug 2005 (CANB).

Pertusaria variabilis is characterised by the sorediate thallus, the absence of apothecia and the presence of methyl 2'-*O*-methylmicrophyllinate. One of the collections (*Elix 37876*) was infected with a lichenicolous *Sphinctrina* sp., consistent with this sorediate crust being a species of *Pertusaria*. The new species is one of a number of sterile *Pertusaria* taxa that are characterised and separated by their chemistry *cf. P. confluentica* and *P. flavopunctata* above. This is the first report of methyl 2'-*O*-methylmicrophyllinate from *Pertusaria*. Previously this rare depside has been identified in *Porpidia contraponenda* (Arnold) Hertel & Knoph and *P. diversa* (Lowe) Gowan (Gowan 1989).

This new species has only been collected from the type locality where it occurs on twigs and branches of trees in monsoon forest.

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New combinations in *Hookerochloa* and *Poa* (Gramineae)

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Abstract

The genus *Austrofestuca* is a synonym of *Poa* with its type species, *A.littoralis* - now a synonym of *Poa billardierei.* The combination ***P. pubinervis*** is made to place this closely related species with *P. billardierei.* The other two species, *A. eriopoda* and *A. hookeriana* belong together in the genus *Hookerochloa* and a new combination is provided for ***Hookerochloa eriopoda.***

Introduction

Alexeev (1976) established *Austrofestuca* (Tzvelev) E.B.Alexeev from *Festuca* subgenus *Austrofestuca*, based on *A. littoralis* (Labill.) Alexeev. Clayton and Renvoize (1986) accepted *Austrofestuca* but stated that the characters used to delimit it required the inclusion of three more Australasian species. Simon (1986) provided the combination for *A. pubinervis* (Vickery) B.K.Simon, and Jacobs (1990) provided combinations for the remaining two, *A. eriopoda* (Vickery) S.W.L.Jacobs and *A. hookeriana* (F.Muell.) S.W.L.Jacobs.

Austrofestuca, *Festucella* E.B.Alexeev, *Hookerochloa* E.B.Alexeev, and *Poa* L. all belong to tribe Poeae subtribe Poinae which includes 15–21 genera as outlined by Soreng et al. (2007). While there had always been some thought that *Austrofestuca littoralis* may have been a species of *Poa* (see Edgar and Connor 2000 for a summary of the synonymy), it was not thought to be a good fit in that genus (Edgar and Connor 2000); the base of the lemma lacks a web and has a dense crown of short hairs to 0.5–0.8 mm long, and the apex said to be muticous or mucronate. Recent DNA studies (Hunter et al. 2004; Gillespie & Soreng 2005; Gillespie et al. 2007, Soreng et al. 2007) have made it clear that *A. littoralis* and *A. pubinervis* are species of *Poa*. Gillespie and Soreng (2005) suggest that *Poa billardierei* (Spreng.) St.-Yves is the appropriate combination in *Poa* to use for *A. littoralis*; the epithet is probably sufficiently distinct from the Australian *P. labillardierei* Steud. (also naturalised in New Zealand) to prevent confusion. Gillespie and Soreng (2005) also point out that most of the characters of *Poa billardierei* (*A. littoralis s.lat.*, including *A. pubinervis*) thought to exclude it from *Poa* occur elsewhere in that genus.

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Hunter et al. (2004) also suggest that both the genera *Festucella* and *Hookerochloa* should be recognised as '...the taxa differ in a wide range of quantitative and qualitative vegetative and reproductive characters...'. They list 14 characters; three of these as discontinuous, viz., (i) leaf blade inrolled vs folded, (ii) glumes smooth vs scabrous, and (iii) caryopsis 3.8–4.5 mm vs 2.6–3.4 mm long. They have two other characters whose character states are worded differently but actually do not differ significantly, viz., (i) abaxial palea surface glabrous to hairy vs glabrous or scabrous, and (ii) habitat descriptions of 'open montane to subalpine forest and grassland' versus 'swampy subalpine to alpine forest and grassland'. We maintain there are two further distinguishing characters that they omitted: leaf width, and a few characters related to this (Jacobs 1990); and epidermal features, where *Festucella* has a coarsely scabrous adaxial epidermis and *Hookerochloa* has a smooth to scabrid adaxial epidermis (Soreng & Gillespie 2007).

As a new edition of Wheeler et al. (2002) is about to be prepared, it has become necessary to clarify the situation and provide any necessary new combinations.

Methods

A total of 39 specimens of each species of *Festucella* and *Hookerochloa* were examined. The specimens (all held at NSW) covered the full geographic range and variation observed in these taxa. The following characters were investigated:

(i) leaf blade inrolled vs folded,

(ii) glumes smooth vs scabrous, and

(iii) caryopsis length.

Cladograms from Hunter et al. (2004), Gillespie and Soreng (2005) and Gillespie et al. (2007) and analyses from Gillespie and Soreng (unpublished data) were used to decide on the generic placement of the species.

The situation with *Austrofestuca pubinervis* was assessed from the literature and specimens.

Results

Hookerochloa/Festucella

(i) *Leaf blade inrolled vs folded*: the leaves are folded or flat in both species; Alexeev (1987) illustrated a folded transection of *Festucella eriopoda* while describing the blade as inrolled. As indicated in Jacobs (1990), the character distinguishing the two is basically leaf width. The leaves of *F. eriopoda* can be very narrow and the folded portion in some cases very small, giving the appearance of rolling. The situation is clearer on specimens with larger leaves.

(ii) *Glumes smooth vs scabrous*: the glumes of both species can be smooth or scabrous. From the specimens held at NSW, smooth glumes are more common in *H. hookeriana* than in *F. eriopoda*, opposite to the situation suggested in Hunter et al. (2004). We conclude that this character does not significantly differ between the species.

(iii) *Caryopsis length*: caryopses were difficult to find in any specimen, but enough were found to indicate that the stated difference does not hold. The figures supplied here would be slightly less than the full potential size, though it is not clear by how much. *F. eriopoda* had seed 3.0–4.1 mm long (mean = 3.6, n = 5) and *H. hookeriana* seeds 3.0–4.2 mm long (mean = 3.6, n = 8). Clearly, in our sample, there were no differences in the seeds lengths between the species.

(iv) *Other characters*: there is a difference in leaf blade width and some associated characters such as number of lateral veins in the blade (Jacobs 1990). There may be a tendency for the degree of hairiness of the abaxial palea surface to differ, but not in any disjunct way. There is a difference in the degree of scabridity of the adaxial leaf surface (Soreng & Gillespie 2007). The important difference in the habitat differentiators suggested by Hunter et al. (2004) is that *H. hookeriana* tends to grow at higher altitudes than *F. eriopoda*.

These are certainly useful characters to discriminate species but are inadequate to use to separate the species into two genera.

The ITS sequences in Hunter et al. (2004) and plastid sequences in Soreng et al. (2007) show good support for a clade containing both species, with *Arctagrostis latifolia* as sister to that clade. While there is good support for several of the final groupings in the cladograms, there is little resolution of the relationships between the groups, a common occurrence with grass gene sequences.

Gillespie and Soreng (2005) did not include either *Festucella* or *Hookerochloa* in their published cladograms, though they did point out that both genera shared slender awned lemmas and a few other characteristics with *Poa* subgen. *Andinae*, now proposed as a new genus *Nicoraepoa* (Soreng & Gillespie 2007). Gillespie and Soreng (unpublished data) also ran analyses with both *Festucella* and *Hookerochloa*; they found that:

(i) in cpDNA *trn*T–*trn*F analyses *Festucella* resolves in a clade with *Arctagrostis* (but this is not well supported being based on a single shared character), and this pair unites in a polytomy with *Hookerochloa* and species of *Nicoraepoa* (with relationships in this clade poorly resolved); and

(ii) in ITS analyses *Festucella* and *Hookerochloa* are sister taxa, *Arctagrostis* forms a clade with *Nicoraepoa*, and these four taxa are united in a strongly supported clade.

In a separate analysis using three independent chloroplast gene sequences (Soreng et al. 2007) *Festucella* and *Hookerochloa* are sisters in a polytomy with *Arctagrostis* and *Nicoraepoa*, without any other taxa, and *Poa billardierei* (actually *P. pubinervis*) is resolved with *Poa*.

These results are similar to those of Hunter et al. (2004).

Austrofestuca pubinervis/*Austrofestuca littoralis*

The lemma apex in both species is entire or occasionally minutely notched with the stout keel extending at the apex as a minute but firm nub <0.1 mm long behind the marginal dents (in side view). An apex with a stout short awn (rarely up to 3 mm long) develops occasionally in *Poa* sect. *Parodiochloa* (C.E. Hubb.) Soreng. These mucros or awns are thicker than the more delicate awns that extend from the lemma apices in the two *Hookerochloa* species.

While the ITS sequences in Hunter et al. (2004) show *A. littoralis* as a clade within *Poa*, few *Poa* species and no other Australian species were included in the analysis. Gillespie and Soreng (2005) included six other Australian species in their cpDNA analysis of relationships in *Poa* and *A. pubinervis* aligns well with the other Australian species in the same major clade in *Poa*. Similar results were obtained with plastid sequence data by Gillespie et al. (2007).

Plastid and ITS data for '*Austrofestuca pubinervis*' or '*Poa billardierei*' s.l., generated by Gillespie and Soreng (2005) and Gillespie et al. (2007: unpublished data) and discussed by Soreng et al. (2007) are all derived from collections of *A. pubinervis* from Western Australia (*Peterson et al. 14510*). When *A. pubinervis* is included in ITS and cpDNA analyses (Gillespie et al. 2007, unpublished data) with sequences of *P. billardierei* s.str. from New Zealand (from Hunter et al. 2004), they come out together with other Australian *Poa* species within *Poa*.

Hunter et al. (2004), quoting Weiller et al. (1995 et seq.), suggest that *A. pubinervis* is doubtfully distinct from *Poa billardierei* [as *A. littoralis*]. The url of Weiller et al. that is quoted no longer appears active but, presuming it is the same text that appears in another url suggesting the same citation, then Weiller et al. do say there is some doubt as to the distinctness of *A. pubinervis* but still treat it as a distinct species and do not synonymise the name. The situation is still as suggested by Simon (1986) viz., the name was provided by Vickery (1939) to replace an earlier invalid name (*Festuca triticoides* Steud.), and the species is maintained as separate in NSW and BRI. There is variation in the hairiness of the lower lemma, as stated by Weiller et al. (1995 et seq.): the Western Australian specimens have lemmas that are hairy below (i.e., *P. pubinervis s.str.*); the specimens from New South Wales have a lemma that is glabrous below (i.e., *P. billardierei s. str.*). Both forms (species) grow in Victoria, Tasmania and New Zealand. The only South Australian specimens seen were too mature to characterise lemma vestiture. It is clear that these two species would benefit from further study. Synonymising the two names is only one option and there are insufficient data to support this option over any other at this stage.

Discussion

Hookerochloa/Festucella

The characters that Hunter et al. (2004) put forward for maintaining *Festucella* and *Hookerochloa* as separate genera are either erroneous or not discontinuous. The situation has not changed since Jacobs (1990) noted that the two species were only reliably separated by leaf blade width or associated characters. There are no good characters to separate the two into different genera.

The sequence data do not support either combining the two into one genus or recognising two genera, but do provide support for treating them as sister taxa. The data do suggest that consideration needs to be given to the relationships with *Arctagrostis* and *Poa* subgen. *Andinae* (for discussion of the latter see Soreng and Gillespie (2007) where this section is elevated to the rank of genus as *Nicoraepoa*). *Arctagrostis* is variously treated as having 1–4 species but all have a single floret per spikelet, acute to mucronate lemmas and a glabrous callus, quite distinct from the floral morphology of both *Festucella* and *Hookerochloa*, which have long-acute awned lemmas and a hairy callus. *Nicoraepoa* is sister to the three genera above and is probably most similar morphologically to *Festucella* and *Hookerochloa* but the sequence data do not support treating all three in one genus. To do so would require including *Arctagrostis* and, if equivalence was to be even vaguely maintained, would require the amalgamation of several morphologically diverse genera from the subtribe Poinae. Both *Festucella* and *Hookerochloa* were published at the same time and have equal priority. We have chosen to combine both under *Hookerochloa.*

Austrofestuca pubinervis

This species undoubtedly belongs in *Poa.* Its status with respect to *Poa billardierei* would certainly benefit from further investigation, but the evidence thus far suggests it is worth maintaining until more complete studies are available. Consequently a new combination is provided in *Poa.*

New Combinations

Hookerochloa eriopoda (Vickery) S.W.L.Jacobs, ***comb. nov.***

Basionym: *Festuca eriopoda* Vickery (1939: 10–11).

Synonyms: *Festucella eriopoda* (Vickery) E.B.Alexeev (1985: 104); *Austrofestuca eriopoda* (Vickery) S.W.L.Jacobs (1990: 602).

Type: Blue Mountains, Kanimbla Valley (Mt Victoria) *J.J. Fletcher* 24.12.1892 (K).

Poa pubinervis (Vickery) S.W.L.Jacobs, ***comb. nov.***

Basionym: *Festuca pubinervis* Vickery (1939: 7), nom. nov. for *Festuca triticoides* Steudel (1855 [1854]: 315) non Lamarck (1791).

Synonyms: *Austrofestuca pubinervis* (Vickery) B.K.Simon (1986: 241); *Austrofestuca triticoides* (Benth.) E.B.Alexeev (1987: 15); *Schedonorus littoralis* var. *triticoides* Bentham (1878: 656).

Type: South-west Australia, *Drummond* 150, (K) n.v.

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The moss-back alga (Cladophorophyceae, Chlorophyta) on two species of freshwater turtles in the Kimberleys

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Abstract

The range of the Australian freshwater alga *Basicladia ramulosa* Ducker is extended, both in its turtle hosts (*Chelodina burrungandjii* Thomson et al.; *Emydura australis* (Grey)) and in geography, to tropical northern Western Australia. Along with further morphological observations, sporangia are described for the first time in this taxon.

Introduction

Moss-back turtles (Fig. 1) have fascinated biologists for many years. While the carapace of a potentially amphibious turtle would be a challenging habitat for most aquatic organisms, it is perhaps surprising there are only a handful of attached algae reported from such sites. Edgren et al. (1953) detailed the range of host turtles then known in North America and the range of epizoic algae that included *Rhizoclonium* and *Cladophora*. Two further genera in the Cladophoraceae are the only macroalgae widely reported on turtle carapaces: the prostrate, spreading, endozoic (and possibly disease causing) *Dermatophyton radicans* Peter, and species of the heterotrichous genus *Basicladia*, responsible for the name 'moss-back'.

In the United States, *Basicladia* is considered a small epizoic genus on turtles and water snails, of three to four taxa (John 2003). Hamilton (1948) described sexual reproduction in North American species of *Basicladia* involving the fusion of biflagellate zooids as is commonly the case in the Cladophoraceae. From unialgal cultures and field experiments, Proctor (1958) provides a natural history of *Basicladia* in North America and contends that *Basicladia* will establish on various substrates if a source of inoculum, a moss-back turtle, is present. Ernst and Norris (1978) added further to the understanding of *B. crassa* and its association with its host. *B. chelonum* is reported by Sherwood et al. (2003) to have been collected on rock in Ho'omaluhia Botanical Garden in Hawai'i but was brought in with imported freshwater turtles.

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In Australia, one species, *Basicladia ramulosa* Ducker, has been described and reported from Victoria and Queensland (Ducker 1958). The purposes of this note are to report its occurrence in northern Western Australia and inland New South Wales (a distribution pattern that almost certainly reflects lack of collecting rather than anything else), to expand the description given by Ducker (1958) to include reproductive structures and make further comments on both prostrate and erect anatomy, and report further host animals. *Cladophora kosterae* van den Hoek, a free living taxon morphologically close to *Basicladia*, has been reported from New South Wales (Skinner & Entwisle 2004).

Methods

Collections were air dried or preserved in 70% ethanol. Slides were stained with aniline blue and mounted in 40% Karo. Examination was done with a Leitz Laborlux D microscope and drawing tube; photomicrographs were taken with a Nikon Coolpix 4500 digital camera and enhanced using Adobe Photoshop. Collections and slides are maintained at NSW.

Description

Basicladia ramulosa Ducker, *Hydrobiologia* 10: 165 (1958)

Type: Victoria: Stratford, on *Chelodina longicollis* (Shaw), *Ducker* s.n., 11 Dec 1956 (MEL? – see notes below, K) *n.v.*

Thallus heterotrichous, consisting of a basal cushion (endozoic) and branched erect axes (epizoic) (Fig. 2), on the carapaces of freshwater turtles (Fig. 1). *Basal system* one or more layers of isodiametric (18–25 µm diam.) or irregular tubular (11–18 µm diam.) cells in and on the substrate (Fig. 3). *Erect axes* filamentous, uniseriate becoming secondarily bi/triseriate by adhesion of lower cells reinforced by downward growth of rhizoids (Figs 4, 5), becoming uniseriate again in upper axis, 34–61 µm diam., or, with buttressing by adhesion, to 91 µm diam., terminal cell truncate, 14–25 µm diam. Branching bifurcate or trifurcate, becoming pseudodichotomous, usually above the lower 3 or 4 cells; laterals with very acute adaxial angle, arising below the endwall (occasionally up to ⅓ below endwall), 17–28 µm diam.; terminal cells truncate 14–16 µm diam. (Fig. 6). *Sporangia* intercalary, thin-walled, 17–32 µm diam., 55–116 (–145) µm long, development acropetal until upper 10–20 cells of branch all sporangia; opening round, projecting, sub-terminally lateral, terminal in apical cell (Fig. 7). Zooids 24–64 per sporangium, 6 × 6–9 µm, uniform, flagella 2.

Distribution: Western Australia, Northern Territory, Queensland, New South Wales and Victoria and probably throughout the continental mainland, on at least *Chelodina burrungandjii* Thomson et al. (2000), *C. longicollis* (Shaw) and *Emydura australis* (Grey). The presence of *C. burrungandjii* in the Kimberley is confirmed in Georges et al. (2002). As the *Chelodina* host is often nomadic, although moss-backs are less frequently encountered than clean backs, it is probable that *Basicladia ramulosa* may be encountered throughout the ranges of the three reported hosts: tropical northwestern Australia for *C. burrungandjii* and *Emydura australis*, and eastern and south-eastern Australia, especially the Murray-Darling system for *C. longicollis. Basicladia duckerae* has yet to be collected from other hosts (turtles, water snails) or found free-living.

It is very likely that the *Cladophora* referred to in Strøm (1921) is *Basicladia ramulosa* also. The locality given for the list of desmids found with the *Cladophora* is the Daly

Fig. 1. Moss-back *Chelodina longicollis*, Copeton Dam Rd, N.S.W. (Photo G.M. Towler)

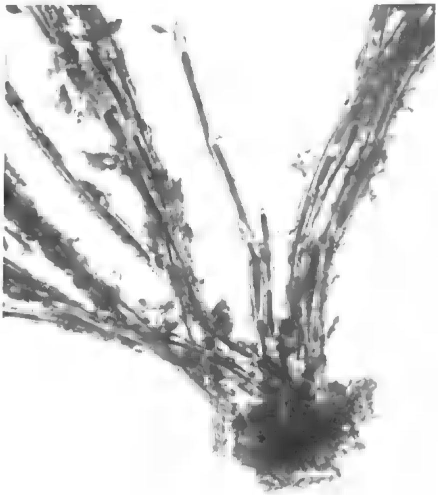

Fig. 2.

Fig. 3.

Fig. 2. Well developed multiseriate axes, *FitzSimmons A5*. Scale bar = 50 µm.

Fig. 3. Interlocking basal cells, *Skinner 0781, McPherson & Towler*. Scale bar = 20 µm.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 4. Biseriate base of erect axis, *Skinner 0781, McPherson & Towler*. Scale bar = 50 µm.

Fig. 5. Rhizoidal reinforcement of lower axis, *FitzSimmons A5*. Scale bar = 20 µm.

Fig. 6. Branching pattern showing narrow adaxial angle, *Skinner 0781, McPherson & Towler*. Scale bar = 20 µm.

Fig. 7. Sporangium with open pore and zooids in formation, *Skinner 0781, McPherson & Towler*. Scale bar = 20 µm.

River, and the host turtle is called *Chelodina oblonga* Gray, identified by Dahl (most likely *C. rugosa* Ogilby as *C. oblonga* is confined to south-western Western Australia).

MEL have been unable to locate the type specimen; it isn't on Doris Sinkora's data base of algal specimens held in MEL and is possibly out on loan.

Specimens examined: Western Australia: Mornington Camp, Annie Creek, Fitzroy R. (17°30' 29"S, 126°06'42"E), on *Chelodina burrungandjii*; ibid, *FitzSimmons A1*, Jun 2004; ibid, *FitzSimmons Cb06*, 8 Jun 2006 (NSW); ibid, on *Emydura australis*, *FitzSimmons 3*, Jun 2005 (NSW); 'pump pool' on Drysdale R. (15°41'37"S, 126°22'03"E), on *Chelodina burrungandjii*, *FitzSimmons A3*; ibid, on *Emydura australis*, *FitzSimmons A4*, Jun 2004 (NSW); Miners Pool, Drysdale R. (15°40'55"S, 126°24'12"E), on *Chelodina burrungandjii*, *FitzSimmons A5/6*, Jun 2004 (NSW); Bell Creek, Isdell R. drainage (17°01'03"S, 125°13'39"E) on *Emydura australis*, *FitzSimmons 2*, Jun 2005 (NSW). **New South Wales:** floodway, Copeton Dam Rd, near Staggy Ck turnoff (29°50'08"S, 150°53'31"E), on back of snake-necked turtle, *Chelodina longicollis*, *Skinner 0781*, *McPherson & Towler*, Oct 2004 (NSW).

Other Australian records: Victoria: Stratford, on *C. longicollis*, *S.C. Ducker*, Dec 1956 (MEL?; K) (Ducker 1958). **Queensland:** Aspley, near Brisbane, *J.E. Coaldrake*, Apr. 1957 (MEL?) (Ducker 1958). **Northern Territory:** lagoons near Daly River, *Knut Dahl*, 1894 (UPS?) (Strøm 1921)

Morphological Observations

Prostrate system: from the sections she made of the prostrate system on and in the *stratum corneum*, Ducker (1958, p 162) concluded that the cells 'in general are round or somewhat angular, ranging from 15 μm to 30 μm in diameter'. The prostrate system in our material appeared filamentous but compacted with multilobed cells interlocking to form the basal cushion from which arose the erect axes (Fig. 3 - it is often difficult to obtain undamaged basal material, with sufficient clearance of cuticle and detritus for good lighting for microphotography and this was the best material available).

Erect axes: Ducker's (1958) descriptions and illustrations of basal cells of recently produced erect axes are verified by our observations. Older, more established bases of erect axes however appear to adhere, and so become multiseriate, becoming buttressed by the extension downwards of close fitting rhizoid-like growths from the cell or cells above (Figs 4, 5). Such multiseriate axes may involve the lower three or four cells in an axis. A similar, but much shorter, downward growth of cells at branches could be observed throughout the axis, except in the fresh growth towards the ends of axes. In some cases fusion between the walls of axial and lateral cells was observed, especially in older parts of the thallus (Figs 2, 4). While speculative, it is inviting to think that both the rhizoidal buttressing and the adhesions are responses to frequent changes in temperature and wetting associated with the turtles' lifestyle.

Reproductive structures: Ducker (1958) does not mention reproductive structures. While no zooids were observed in Western Australian material (the material arrived either dry or already preserved) some upper cells in young filaments were modified as sporangia, thin walled, L/D 1.5– 4, with a subterminal funnel-like pore. The New South Wales material had well developed moniliform sporangial series, with mature, discharging and empty sporangia.

Hoffmann and Tilden (1930) described the sporangia in *B. crassa* as short and almost as broad as long, with the pore in various positions. This form of sporangium differs from that described by Hoffmann and Tilden (1930) for *B. chelonum*, and by van den

Hoek (1963) for *C. kosterae* and *C. okamurai* (Ueda) van den Hoek, all of which have (sometimes multiple) lateral pores close to the middle of the sporangium. Hamilton (1948) found that the North American species released biflagellated gametes from sporangia in moniliform series, sometimes up to 18 in *B. crassa*, opening through a lateral pore. His illustration (Plate 1, figs 3–5) indicates that the pore in *B. chelonum* may be displaced towards the top of the sporangium rather than precisely central. The position and number of pores in sporangia needs further examination before it can be used reliably to discriminate between taxa.

Acknowledgments

This paper is dedicated to the memory of Sophie Ducker (1909–2004) who did so much for the study of algae, marine and freshwater, in Australia. Dr FitzSimmons was supported by Earthwatch Institute and the Hermon Slade Foundation. The turtle apprehended near Copeton Dam was encountered during a survey of freshwater algae in the Border Rivers and Gwydir Catchment Management Area, supported by a Hermon Slade Foundation grant. Thanks to Gillian Towler and Hannah McPherson for the 'moss-back' photograph, and helping with collection, Julia Sideris for much work on the photomicrographs and Peter G Wilson for advice on taxonomic matters.

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Three new species of *Indigofera* (Fabaceae: Faboideae) from Cape York Peninsula

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Abstract

Three new species of *Indigofera* are described: ***Indigofera elachantha*** Peter G. Wilson & Rowe, a species related to *I. pratensis* but distinguished by its slender inflorescence axis and rather small flowers, ***Indigofera polyclada*** Peter G. Wilson & Rowe, distinguished by its semi-prostrate multi-stemmed habit and very sparse indumentum; and ***Indigofera wannanii*** Peter G. Wilson, a recently discovered species with probable affinities to *I. bancroftii* and *I. tryonii*. All species are illustrated and their conservation status discussed.

Introduction

To date, there have been only two named endemic species of the genus *Indigofera* in that portion of Cape York Peninsula north of Laura. These are *Indigofera pratensis*, a species with a range that stretches from just north of Brisbane to the Portland Roads/Weipa area, and *I. polygaloides*, a poorly known species with collections from scattered localities across northern Australia (Wilson & Rowe 1994). Bailey (1900), in his *Queensland Flora*, suggested that *I. saxicola* F. Muell. also occurred in Queensland, in the 'Gulf Country' but did not indicate any particular collection. However, *I. saxicola* was originally described from the Northern Territory and no specimen from Bailey's time can be found in the Queensland Herbarium bearing this name. It now seems very likely that Bailey's inclusion of this species was based on information received from Mueller. In the Melbourne Herbarium, there are a number of specimens collected by Stephen Johnson from "Stuarts River" (=Stewart River, south of Coen) in 1891 on which Mueller has written 'saxicola' in pencil on the labels. Subsequently, this name has been applied to a few specimens from Cape York that show similarities to *I. pratensis* but have more rounded leaves and smaller flowers, characters that make these plants somewhat reminiscent of *I. saxicola*. In a hand-written note attached to one specimen (MEL 584598), Mueller has noted a further distinctive characteristic of this plant, viz. "fruit not deflexed". This species is here named *I. elachantha*.

The two other new Cape York species described here are currently known from only one or two locations. Both are low-growing subshrubs that have slender stems arising from an underground rootstock. With this habit, both species could easily be overlooked and the above-ground parts might disappear during the dry season, particularly if there had

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been local burning. These two species differ markedly from each other in flower size and indumentum and are described below as *I. polyclada* and *I. wannanii.*

Indigofera elachantha Peter G. Wilson & Rowe, *sp. nov.*

Indigofera pratense affinis sed axibus inflorescentiarum tenuioribus, floribus multo minoribus, foliolis plus minusve late ellipticis, fructibus ascendentibus differt.

Holotype: Queensland: Cook: 25 km north of Duck Holes Creek on the Peninsula Developmental Road (14°13'S, 143°17'E), *J.R. Clarkson 8940 & V.J. Neldner*, 17 Apr 1991 (NSW). Isotypes: BRI, DNA, K, L, MBA, PERTH (all n.v.).

I. saxicola auct. non F. Muell., F.M. Bailey, Qld Flora 2: 388 (1900)

Erect shrub, 1–1.5 m high; young stems ridged, dark brown (young foliage grey–green), strigose with dense, appressed to shortly spreading, equally biramous hairs. Leaves pinnate, with (5–)7–13 leaflets; stipules narrowly triangular, 1.7–4.2 mm long, pubescent, not spinescent, not persistent; petiole 2.5–7 mm long; rachis furrowed, multicellular hairs between leaflet pairs sparse to dense, conspicuous or inconspicuous, red or brown, club-shaped. Leaflets opposite; stipellae conspicuous, 0.5–1.2 mm long; lamina elliptical to obovate, 10–34 mm long, 6–23 mm wide; upper surface green, with sparse, appressed hairs; lower surface grey-green (paler than above), with sparse, appressed hairs; apex apiculate; veins slightly prominent above and not prominent below. Inflorescences 45–165 mm long, longer than leaves; peduncle 5–22 mm long; bracts triangular, 0.9–1.5 mm long; flowers pink to purple; pedicel 1.3–2.5 mm long. Calyx 1.4–2 mm long, with subequal lobes less than the length of the tube, clothed with sparse to moderately dense, hyaline, white to brown, appressed hairs. Standard pale pink, broadly obovate to ovate, 4.2–5.5 mm high, 3–4.5 mm wide. Wings oblong to spathulate, 4.2–5.5 mm long, 1–1.5 mm wide. Keel 4.5–5.7 mm long, 0.8–1.8 mm deep; apex acute to rounded; lateral pockets 1.1–1.5 mm long; hairs moderately dense, along the bottom. Staminal tube 3.1–4.5 mm long, colourless. Ovary glabrous. Pod ascending, terete, 25–46 mm long, 2.5–4 mm deep, dark brown or grey, glabrous; apex pointed or shortly beaked; endocarp spotted. Seed 5–7 per fruit. (Fig. 1).

Notes: this species is a member of the *I. pratensis* group and is most similar to *I. saxicola.* It differs from the latter by the glabrous ovary and fruit, the ± rounded (as opposed to distinctly pointed) bud, and the very slender inflorescence axis. It is readily distinguished from *I. pratensis* by the much smaller flowers (keel <7 mm long cf. 10–14 mm). It differs from both by the ascending fruits. Specimens have been collected at only a small number of scattered sites and show some, perhaps significant, geographic variation. Northern collections (from the Pascoe River area) have 9–11 or more leaflets while southern collections (from between Coen and the Palmer River) consistently have 5–7 leaflets. We did consider separating these as subspecies but the floral and inflorescence characters are so distinctive that we have refrained from recognising subspecies pending further collections. There is a single specimen, the only one to have been collected from between Wenlock and Coen (13–14° S), that has 7–9 leaflets; this area should be investigated further.

The epithet is derived from the Greek *elachos*, small or short, and *anthos*, flower.

Distribution and habitat: Queensland; known from scattered sites in Cape York between Hann Creek and south of the Palmer River (c.12°30' –16°30'S). It is recorded from rocky or sandy soil in *Leptospermum* scrub or open eucalypt woodland.

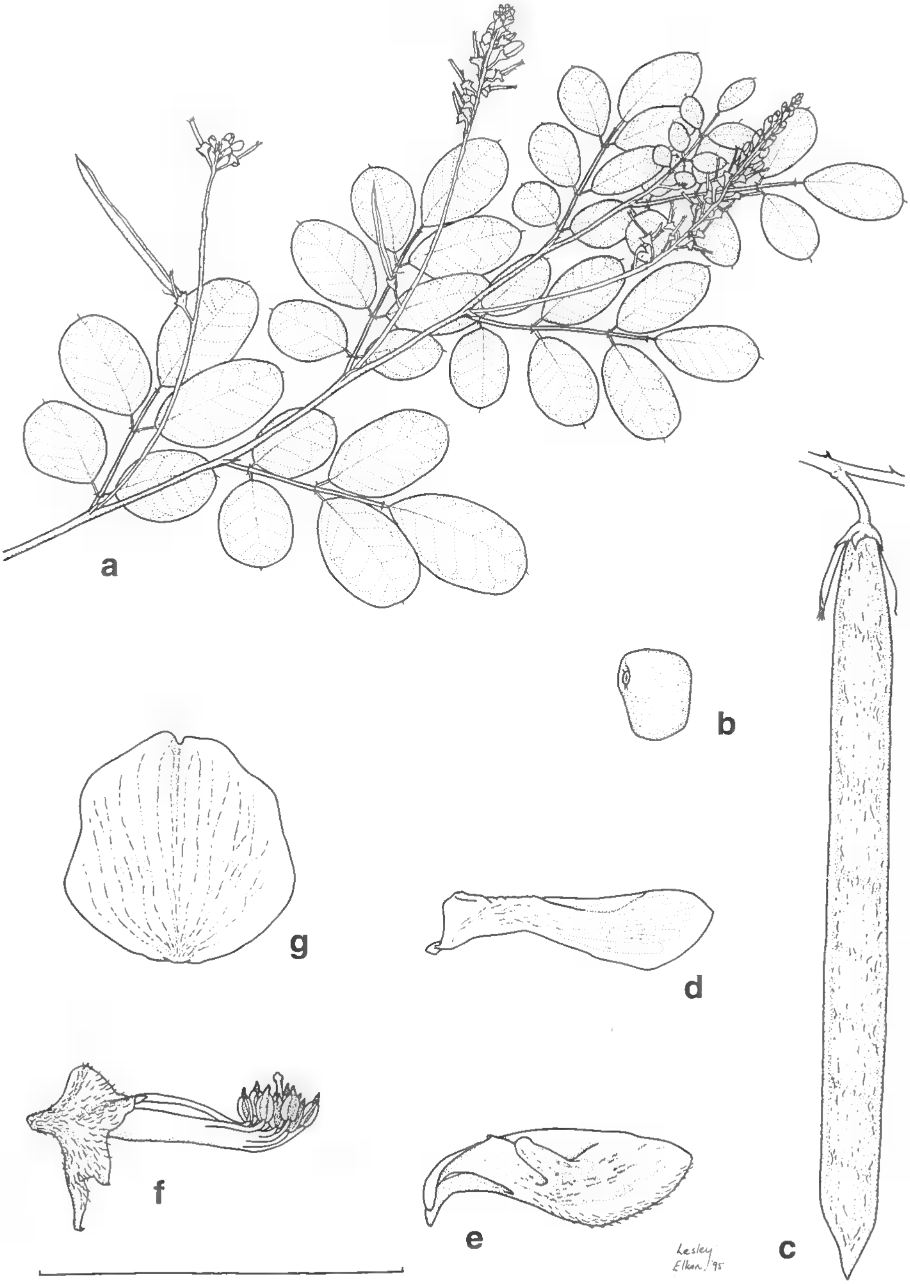

Fig. 1. *Indigofera elachantha.* **a**, habit; **b**, seed; **c**, fruit; **d**, wing; **e**, keel; **f**, lateral view of calyx and androecium; **g**, standard. (a, c from *Clarkson 8940 & Neldner*, b, d–g from *Clarkson 6657& McDonald*). Scale bar: a = 50 mm; b = 10 mm; c = 20 mm; d–g = 7.5 mm.

Conservation status: this species is reportedly common at many sites (B. Wannan pers. comm.) and does not appear to be at risk; and is assessed as "least concern" using IUCN criteria (B. Wannan pers. comm.).

Selected specimens: Queensland: Cook: near Nelson Creek, Jacky Jacky Range, *Wannan 3681 & Wardrop*, 18 Jul 2004 (BRI, NSW); 1 km N of Maloneys Springs, *Forster 5288*, 19 Jun 1989 (BRI, MO); Head of Hann Creek, 46.5 km from Moreton Telegraph Station, *Forster 4560*, 27 Jun 1988 (BRI, MEL); Brown's Creek, Pascoe River, *Brass 19176*, 13 Jun 1948 (CANB, BRI); Flinders Island, *Smyth s.n.*, 1978–1980 (BRI); Stuarts [Stewart] River, *Johnson s.n.*, 1891 (MEL); c. 15 km W of Coen, *Clarkson 10130 & Neldner*, 31 Jul 1993 (NSW); 19 km S of the Palmer River crossing on the Peninsula Development Rd, 1 km N of the Mareeba–Cook shire boundary, *Clarkson 6657 & McDonald*, 4 Mar 1987 (BRI, NSW).

Indigofera polyclada Peter G. Wilson & Rowe, *sp. nov.*

Indigofera pratense fortasse affinis sed caulibus laxis pergracilibusque, foliolis minoribus et inflorescentiis multo brevioribus differt.

Holotype: Queensland: Cook: east of Weipa on the Peninsula Development Road, *B.S. Wannan 1589 & R.L. Jago*, 24 Feb 2000 (NSW). Isotype: BRI.

Spreading to prostrate subshrub, with woody rootstock; young stems terete, green to brown, glabrous or strigose with sparse, appressed, equally biramous hairs. Leaves pinnate, (9–)13–19(–21) leaflets; stipules linear to subulate, 2–3 mm long, glabrescent, not spinescent, not persistent; petiole 1.5–3.5 mm long; rachis furrowed, multicellular hairs between leaflet pairs few or absent. Leaflets opposite or sometimes sub-opposite; stipellae slender, 0.2–1.2 mm long; lamina elliptical to obovate, (3.5–)5–10 mm long, 1.5–4 mm wide; upper surface green, glabrous; lower surface green, with sparse, appressed hairs; apex apiculate, 0.3–0.5 mm long; midrib impressed above and prominent below; other venation reticulate or obscure. Inflorescences 15–25 mm long, shorter than to equal to leaf; peduncle 10–17 mm long; bracts narrowly triangular, 0.5–0.7 mm long; flowers probably pink to purplish; pedicel 0.8–1.5 mm long. Calyx 1.2–1.4 mm long, with subequal lobes slightly shorter than the length of the tube, clothed with sparse to moderately dense hyaline appressed hairs. Standard suborbicular, 3.8–4.3 mm high, 3.6–4.0 mm wide. Wings spathulate, c. 4.5 mm long, 2 mm wide. Keel c. 5 mm long, 1.5 mm deep; apex acute; lateral pockets c. 0.5 mm long; hairs sparse, hyaline, at the tip. Staminal tube 2.5–3.5 mm long, colourless. Pod ascending to spreading, terete, (17–)20–27 mm long, 2–3 mm deep, brown, glabrous or glabrescent; hairs sparse, appressed; apex pointed or shortly beaked; endocarp very faintly spotted. Seed (4–)6 per fruit. (Fig. 2).

Notes: known only from two collections. The slender, loose, multi-stemmed habit of this species differs dramatically from any other Australian species. Its relationships are unclear; it shows some similarities to the *I. pratensis* group but it differs from all members of this group by its relatively short inflorescences, the non-angular stems and the glabrous adaxial surfaces of the leaves. In these latter features it approaches the *I. australis* group where it most closely resembles *I. baileyi* in habit.

The epithet, derived from the Greek, refers to the numerous stems arising from the underground rootstock.

Distribution and habitat: only known from central Cape York where it is reported from open eucalypt (*Corymbia hylandii*) woodland on yellow earth with ironstone gravels.

Conservation status: the habit of the plant suggests that it would be unaffected by fire as it is likely to die back to the rootstock in the dry season and resprout and flower in response to summer rain. However, fire frequency could have an impact on breeding success if fruit set and recruitment from seed were affected. While threat levels from occasional fire might be low, the paucity of records suggests that, following IUCN criteria, this species should perhaps be regarded as endangered until further field surveys can be conducted. Its potential habitat has been modelled based on geology and, so far, preliminary searches have failed to find the species at other than the two known locations (B. Wannan pers. comm.).

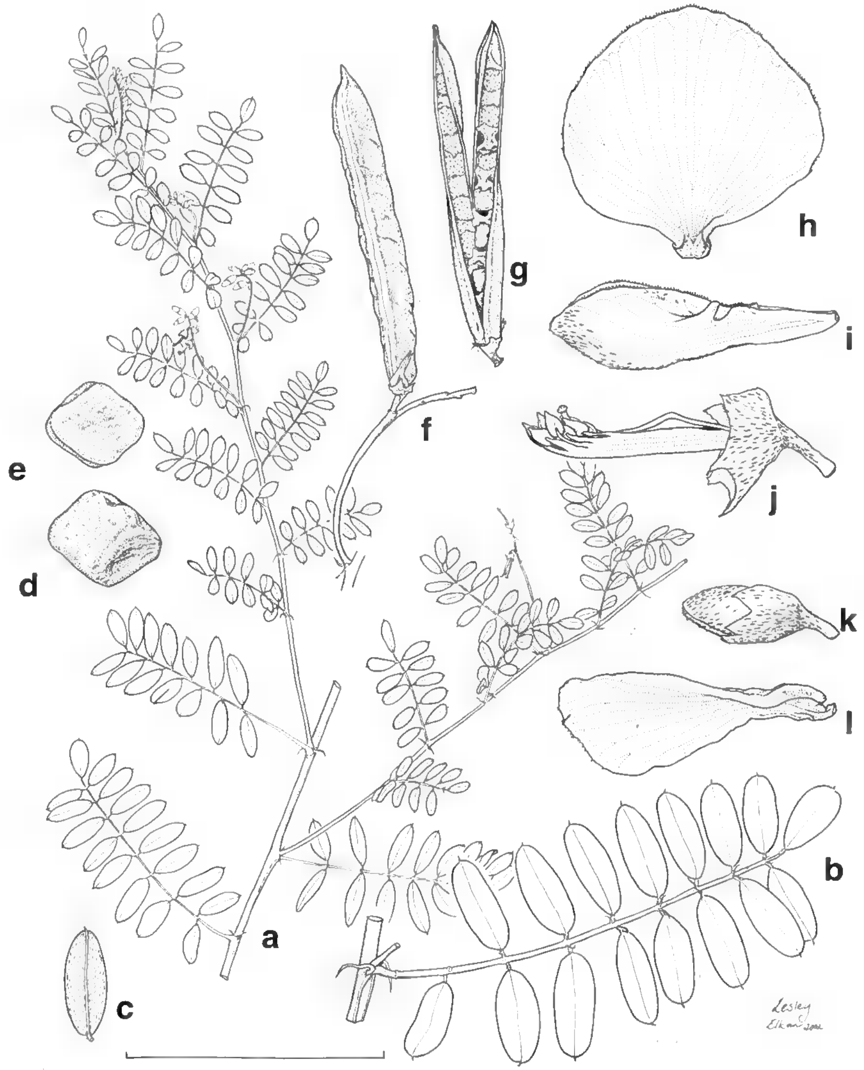

Fig. 2. *Indigofera polyclada*. **a**, habit; **b**, leaf; **c**, leaflet (abaxial view); **d**, **e**, seed; **f**, **g**, fruit; **h**, standard; **i**, keel; **j**, lateral view of calyx and androecium; **k**, bud; **l**, wing. (a–c, h–l from *Wannan 1589 & Jago*; d–g from *Clarkson 8500 & Neldner*). Scale bar: a = 40 mm; b–c, f–g = 20 mm; d–e, h–l = 5 mm.

Other specimen examined: Queensland: Cook: 4.3 km S of the Wenlock River on the Peninsula Development Road, *Clarkson 8500 & Neldner*, 22 Apr 1990 (BRI, NSW, K).

Indigofera wannanii Peter G. Wilson, ***sp. nov.***

Indigofera tryonii persimilis sed foliolis maioribus non valde discoloribus, fructibus longioribus differt.

Holotype: Queensland: Cook: East of Musgrave on road to Marina Plains (14°45'04"S, 143°33'57"E), *B.S. Wannan 4685 & J. Beasley*, 6 Mar 2007 (NSW). Isotypes: BRI, CANB, CNS, K, MEL, MO, US.

Prostrate subshrub to 0.1 m high, with woody rootstock; young stems angular, somewhat flexuose, green to greyish, tomentose with moderately dense, hyaline to greyish, spreading, ± equally biramous hairs. Leaves pinnate, (15–)19–29 leaflets; stipules subulate, (2–)2.5–4.5(–5) mm long, pubescent, not spinescent, semi-persistent; petiole 1.5–4.5(–8) mm long; rachis furrowed, multicellular hairs between leaflet pairs dense, conspicuous, red to dark brown, club-shaped. Leaflets opposite; stipellae absent or inconspicuous, to 0.6 mm long; lamina oblong to narrowly elliptical or elliptical, 8.5–17 mm long, 2.2–6 mm wide; upper surface green, with moderately dense, appressed hairs; lower surface pale green, with moderately dense, appressed to shortly spreading hairs; apex apiculate; reticulate veins usually conspicuous adaxially. Inflorescences 55–100 mm long, a little longer than the leaves; peduncle 20–50 mm long; bracts narrowly triangular to linear, 0.6–1 mm long; flowers pink-purple; pedicel 0.7–1 mm long. Calyx 1–2 mm long, with unequal lobes, less than the length of the tube, clothed with moderately dense to dense, hyaline to white, shortly spreading hairs. Standard deep pink to purplish, elliptical to obovate, 8.2–9.5 mm high, 5–6.5 mm wide; hairs moderately dense, hyaline to yellowish; apex obtuse with a short apiculum. Wings deep purplish pink, oblong, to 7 mm long, 2 mm wide. Keel 7–8.8 mm long, 2.2–2.5 mm deep; apex acute; lateral pockets 1–1.4 mm long; hairs moderately dense, hyaline, at the tip and along the bottom. Staminal tube 6–7 mm long, pigmented (particularly on the adaxial side). Ovary moderately to densely hairy. Pod descending to deflexed, cylindrical, 23–39 mm long, 2–3(–4) mm deep, brown, tomentose; hairs moderately dense, appressed to shortly spreading; apex beaked; endocarp spotted. Seed (4–)6–8 per fruit. (Fig. 3).

Notes: in its ± prostrate habit, this species most closely resembles *I. tryonii* but differs from it in its larger leaflets that are not strongly discolorous, and in the longer fruit.

This species is named for the author's friend and colleague, Bruce Wannan, who discovered it.

Distribution and habitat: only known from the type locality where it occurs in open eucalypt (*Eucalyptus tetrodonta*, *E. cullenii*, *Corymbia hylandii*, *C. nesophila*) and *Erythrophleum* woodland on substrates derived from metamorphic rocks.

Conservation status: this species also has a perennial rootstock so the impact of fire would be much the same as for *I. polyclada*. However, since the single known locality is threatened by gravel extraction, this species is provisionally assessed, following IUCN criteria, as critically endangered until a more thorough survey can be carried out. This species' potential distribution has likewise been modelled based on geology but has not as yet been located at other sites (B. Wannan pers. comm.).

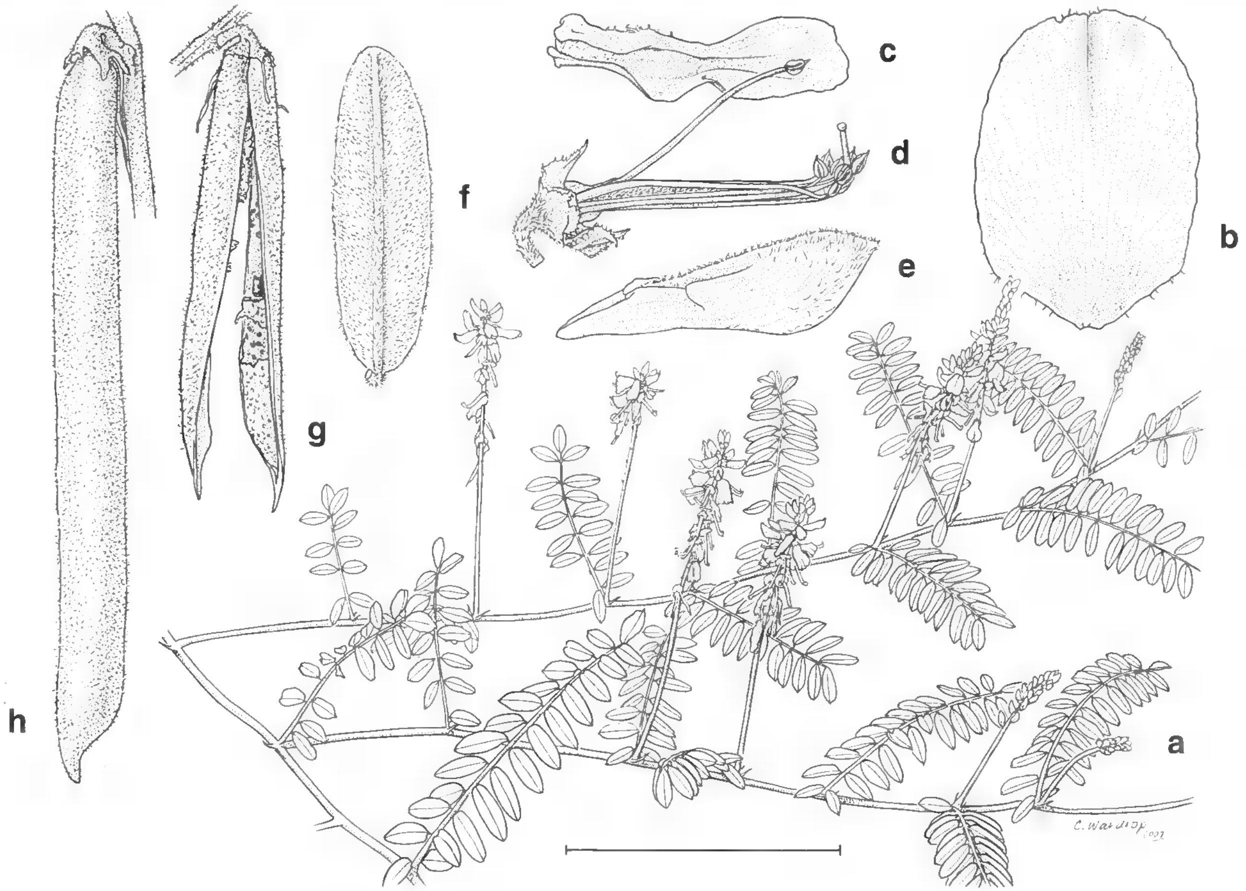

Fig. 3. *Indigofera wannanii.* **a**, habit; **b**, standard; **c**, wing; **d**, lateral view of calyx and androecium; **e**, keel; **f**, leaflet, abaxial surface; **g**, open fruit; **h**, unopened fruit. (a from a photograph of *Wannan 4685*; b–e from *Wannan 4685 & Beasley*; f, h from *Wannan 4512 & Graham*; g from *Wannan 3595 & Graham*). Scale bar: a = 85 mm; b–e = 8 mm; f–h = 15 mm.

Other specimens examined: Queensland: Cook: East of Musgrave, *Wannan 3595 & Graham*, 4 Jun 2004 (BRI, CANB, NSW); East of Musgrave, beside road to Marina Plains, *Wannan 4512 & Graham*, 17 Jun 2006 (BRI, NSW).

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A revision of the Indigofereae (Fabaceae) in Australia. 2. *Indigofera* species with trifoliolate and alternately pinnate leaves

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Abstract

The second part of a revision of the tribe Indigofereae (Fabaceae) occurring in Australia is presented, covering those species with consistently trifoliolate leaves and the pinnate-leaved species with leaflets alternate on the rachis. Ten species are considered here: five are introduced, four are native and one is endemic. A neotype is chosen for *Indigofera glandulosa* Wendl. and a lectotype for its synonym *Psoralea leichhardtii* F.Muell.

Introduction

In our first paper on Indigofereae in Australia (Wilson & Rowe 2004) we revised *Indigastrum* and the simple or unifoliolate species of *Indigofera*. Here we consider a further set of species that fall into two broad groups: those with consistently trifoliolate leaves and those with alternate leaflets. Almost all the alternate leaflet group are introductions to Australia and, with one exception, the remaining species included in this paper are native but not endemic. The single endemic species, however, is clearly related to species that occur outside Australia.

Characters

Particular care should be taken with one of the introduced species that has alternate leaflets: *Indigofera oblongifolia*. This species has a low leaflet number (usually 1–3) and may be mistakenly assessed as being either unifoliolate or trifoliolate.

In this paper, hairs are described as sparse when they are well separated and the stem or leaf surface is clearly visible, as moderately dense when the hairs are separated by the length of one arm of the biramous hair (or thereabouts), dense when the arms overlap but do not fully conceal the epidermis, and very dense when the epidermis is completely concealed.

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Trifoliolate Species

The trifoliolate species fall into two groups morphologically, although both groups lack a feature commonly found in *Indigofera*: endocarp spots. The first group, of two species, is characterised by having conspicuous discoid glands on the lower surface of the leaflets. These species are currently placed in section *Laxiflorae* Wight & Arn. although it should be noted that similar glandular structures occur in other sections (Schrire 1995). A common feature of the second pair of species is the distinctive 4-angled fruit, which is a diagnostic, but not unique, attribute of section *Tetragonocarpae* Wight & Arn. The latter section also contains a number of species with pinnate leaves, including the Australian *I. ewartiana* Domin, so this section is not restricted to species with trifoliolate leaves.

When working the following key, users should be aware that a few species with pinnate leaves occasionally have some trifoliolate leaves, but leaves with 5 or more leaflets are always present. These species are: *I. boviperda* (inland populations), *I. georgei* s. lat., *I. ewartiana* (see Wilson & Rowe 1994) and some intergrades between *I. schultziana* and *I. saxicola*.

Key to trifoliolate species

1 Discoid glands on lower surface of leaflets conspicuous 2

1 Discoid glands on lower surface of leaflets absent 3

2 Leaves pinnately trifoliolate (rachis extended 2.5–4.5 mm); discoid glands brown to black; fruit 5–6 m long, 2-seeded .... ***I. glandulosa***

2 Leaves ± digitately trifoliolate (rachis extended only c. 1 mm); discoid glands orange; fruit usually 7–15 mm long, 3–9-seeded .... ***I. trifoliata***

3 Inflorescences mostly <40 mm long, shorter than the leaf .... ***I. trita***

3 Inflorescence mostly >40 mm long, longer than the leaf .... ***I. polygaloides***

Indigofera glandulosa Wendl., Bot. Beob. 55 (1798)

Type citation: 'Vaterland: Ostindien. ⊙'

Neotype (designated here): 'Ind. Or. Roxburgh 1789' (Smith Herbarium, sheet 1213.16, LINN, right-hand specimen)

Indigofera glandulosa Roxb. ex Willd., Sp. Pl. 3(2) : 1227 (1803)

Type citation: 'Habitat in India orientale. ⊙ (v.s.)'

Type: *Klein 750*, 19 Nov 1794 (B-W, photo seen)

Psoralea leichhardtii F. Muell., Fragmenta 4: 22 (1863)

Type citation: 'Ad flumen Comet River. Dr. L. Leichhardt. D. Bunce.'

Lectotype (designated here): Queensland: Comet River, *Leichhardt 446*, [1847] (MEL 585912). Probable isolectotype: K

Illustration: de Kort & Thijsse (1984) fig. 2q [fruit].

Erect annual or short lived perennial herb, 0.2–0.7 m high, with taproot; young stems ridged, green to yellowish or brown, hirsute with dense, spreading, unequally biramous hairs. Leaves pinnately trifoliolate; stipules narrow and triangular, 1.5–3 mm long, glabrescent, not spinescent, not persistent; petiole 9–21 mm long; rachis furrowed; multicellular hairs between leaflet pairs absent or sparse, inconspicuous, orange, club-shaped. Leaflets opposite; stipellae absent; lamina narrow to broadly obovate, 8–37 mm long, 3.5–17 mm wide; upper surface green; with sparse to moderately dense spreading hairs; lower surface grey to green with conspicuous light brown to black discoid glands and moderately dense spreading hairs; apex obtuse and shortly mucronate; veins not prominent. Inflorescences 5–20 mm long, shorter than leaves; peduncle 0.5–1 mm long; bracts linear to narrowly triangular, 0.7–1.1 mm long; flowers pink to purple or red; pedicel 0.9–1.5 mm long. Calyx 1.5–2.4 mm long; lobes subequal, longer than the length of the tube and covered with moderately dense, white to brown, shortly spreading hairs. Standard pink to red, elliptical to obovate, 3–3.7 mm long, 1.9–2.1 mm wide. Wings spathulate, 2.5–3.6 mm long, 0.8–1.1 mm wide. Keel 3.2–3.8 mm long, 1.2–1.4 mm deep; lateral pockets 0.5–1.1 mm long; apex acute to rounded; hairs moderately dense, hyaline to brown, at the tip and along the bottom. Staminal tube 2.4–3.2 mm long, colourless. Ovary densely hairy. Pod spreading to deflexed, shortly cylindrical with membranous, toothed wings, 5–6 mm long, 2.5 mm wide, brown, hirsute; hairs sparse to moderately dense, somewhat spreading; apex shortly pointed; endocarp not spotted; seeds 2 per fruit.

Notes: Wendland's type of *Indigofera glandulosa* has not been located. De Kort &Thijsse (1984) cite the type as 'Herb. Wendland (Hannover, destroyed)' but Stafleu and Cowan (1988) indicate that Wendland's types are at Göttingen (GOET). We have enquired at Göttingen but the type of this taxon was not found in that herbarium (Jochen Heinrichs, pers. comm. 2007). De Kort and Thijsse (1984: 120) further suggest that Wendland's type may have been a duplicate of the collection used by Willdenow when he later published the same name. These authors say 'Willdenow referred to Roxburgh, who wrote this name on the herbarium label' but this is not quite correct. Willdenow attributed the name to Roxburgh but the specimen itself was collected by Johann Gottfried Klein (an associate of Roxburgh's) in November 1794. Furthermore, judging from Willdenow's annotation, this specimen appears only to have reached Europe in 1802. On the other hand, the Roxburgh specimen in the Smith Herbarium (at LINN) is dated 1789 and is more likely to represent a duplicate of material Wendland may have seen. This seems a plausible scenario, but the uncertainties surrounding typification of this taxon have led us to choose one element on the sheet at LINN as neotype rather than as lectotype.

The MEL specimen of *Psoralea leichhardtii*, despite not having Mueller's binomial on the label, has been chosen as lectotype since it bears Leichhardt's own collecting tag. The sheet at K, ex Herbarium Hookerianum but originally from Mueller's herbarium, does have Mueller's binomial on the label but also contains a packet of fragments from a later collection by P.A. O'Shanesy. The two Leichhardt specimens are almost certainly part of a single gathering. Daniel Bunce, cited by Mueller as co-collector, was a gardener and botanist who accompanied Leichhardt on his second journey, but no reference to him can be found on either specimen, or any other specimen of this taxon. Bunce (1859) published an account of this expedition and reports that Leichhardt's party was in the vicinity of the Comet River twice. The first time was between February 13 and March 4, 1847, and Bunce (1859: 138) records that he collected 'several *Leguminous* plants having pink blossoms' on February 18, which may have included this species. On the return trip, they traversed the same region between 22 June and 3 July of the same year but Bunce (1859: 195) records that they travelled in 'forced and hurried stages', so it is less likely the type was collected then.

Distribution and habitat: in Australia this species has been found at scattered locations in Queensland, the Northern Territory and Western Australia; it is recorded on dark brown clay loams, frequently on land under cultivation. Although apparently rather rare (it hasn't been collected in Australia for around 30 years), its occurrence on cultivated land has led to its designation as a weed (Lazarides et al. 1997). The species is here accepted as native to Australia, although with some doubt; it is also known from India and Indonesia where it is recorded from similar habitats.

Selected specimens: Queensland: Leichhardt: Lenton Downs, about 50 miles WNW of Nebo, *Johnson 2311*, 8 May 1962 (BRI); Clermont district, *Wilkins 2*, 9 Mar 1943 (BRI); Buckleton, Springsure, *McLaughlin s.n.*, May 1943 (BRI 232751). North Kennedy: Cashmere, *Armit 155*, 20 Mar 1875 (MEL 586621); Cunjuboy Station, between Hughenden and Mt Garnet, *A. Wilson s.n.*, 10 Mar 1952 (BRI). Port Curtis: Neerkool Creek, *Bowman 15*, 1862 (MEL 585910); Alton Downs, near Rockhampton, *Blank s.n.*, Apr 1921 (BRI 232752). South Kennedy: Logan Downs, Clermont, *Bowden 2*, Mar 1958 (BRI). **Western Australia:** Gardner: Block 68, sugar cane experimental area, Dept. Agriculture, Kununurra, *Aplin 6285*, 10 Mar 1978 (PERTH, NSW). **Northern Territory:** Darwin & Gulf: 4 miles NW of Katherine, *I. Wilson 49*, 2 Jan 1965 (DNA); Old Station Springs, Mountain Valley Stn, *Swinbourne 712*, 26 Feb 1963 (CANB, MEL, NSW).

Indigofera polygaloides M. Scott, Kew Bull. June 1915: 88 (1915) non Gagnepain (1916)

Holotype: Northern Territory: Pine Creek, *C.E.F. Allen 85*, Feb 1914 (K, photo seen). Possible isotype: NSW

I. amaliae Domin, Biblioth. Bot. 89: 188 (1928)
Lectotype (see Wilson & Rowe 1994: 643): Queensland: [Rockhampton] *Dietrich 1854*, [Feb 1866] (PR 527202). Isolectotypes: PR 527203, HBG, CANB 282834, MEL.

Prostrate or trailing perennial herb, 0.1–0.3 m high, with thickened or swollen taproot; young stems ridged, green, strigose with moderately dense, appressed, equally biramous hairs. Leaves trifoliolate; stipules narrowly triangular or linear, (1–)2–4 mm long, sparsely pubescent, not spinescent, persistent but not thickened or woody; petiole 3–13 mm long; rachis furrowed; multicellular hairs between leaflet pairs absent. Leaflets opposite; stipellae rarely absent to usually inconspicuous, 0.3–1 mm long; lamina elliptical to obovate, 5–15(–24) mm long, 3–10(–14) mm wide; upper surface green, with sparse to moderately dense, somewhat spreading, unequally biramous hairs; lower surface green (paler than above), with sparse to moderately dense, appressed, equally biramous hairs; apex obtuse and apiculate; veins not prominent. Inflorescences (15–)40–120(–360) mm long, longer than leaves; peduncle 5–20(–39) mm long; bracts triangular, 0.5–2 mm long; flowers pink to purple; pedicel 0.5–1 mm long. Calyx (2–)2.5–4 mm long; lobes subequal to equal, longer than the length of the tube and covered with moderately dense, white, appressed hairs. Standard pink, obovate, 4–5 mm long, 3.2–4.7 mm wide. Wings narrowly obovate to spathulate, 4–5.5 mm long, 1.3–2 mm wide. Keel 4.5–5 mm long, 1.2–2 mm deep; apex rounded; lateral pockets 0.5–1.2 mm long; hairs sparse, hyaline to white, along the bottom; margin ciliate. Staminal tube 3–4 mm long, colourless. Ovary glabrous to sparsely hairy. Pod ascending to descending, terete with lateral ridges, (10–)20–30 mm long, 1.5 mm wide, brown, strigose to glabrescent; hairs sparse to moderately dense, appressedapex acute, sometimes kinked upwards; endocarp not spotted. Seeds 7–10 per fruit.

Note: see Wilson and Rowe (1994) for discussion of typification and variation.

Distribution: Queensland, Northern Territory, and Western Australia (see Wilson & Rowe 1994: fig. 2); it is found on stony slopes or plains and generally sandy soils in open woodland or sometimes in cleared areas.

Conservation status: Albrecht et al. (1997) suggest a coding of 3k for this species indicating that it is poorly known in the Northern Territory. However, *I. polygaloides* does not appear on the current Threatened Species List for the Northern Territory.

This taxon is still under-collected across its range and there have been no recent collections from the North Kennedy and Leichhardt districts of Queensland. Without assessment of the extent of populations and potential threats, this taxon should be considered 'Data Deficient' under current IUCN criteria (IUCN 2001).

Selected specimens: Queensland: Cook: Horn Island, *Clarkson 6477*, 10 Apr 1986 (BRI, MBA, NSW); 10 km south of the Palmer River crossing on the Peninsula Development road, *Clarkson 6667 & McDonald*, 4 Mar 1987 (BRI, MBA, NSW, QRS). Port Curtis: 'Nullegar', about 2 km west of house, *Anderson 854*, 19 Apr 1979 (BRI); 'The Springs', 20 km N of Glen Geddes, *Anderson 2944*, 2 Mar 1982 (BRI); State Forest 473, *Forster 16304*, 19 Feb 1995 (BRI, NSW). North Kennedy: Bowen River, *unknown coll.*, no date (MEL). Leichhardt: Peak Downs, *Mueller s.n.*, (MEL, NSW). **Western Australia**: Gardner: behind Paspaley pontoon in Port George, *Mitchell 2328 & Willing*, 6 Apr 1992 (NSW, PERTH); Water Supply Creek, Freshwater Bay, *Mitchell 2874*, 23 Mar 1993 (NSW, PERTH). **Northern Territory**: Darwin & Gulf: 4 miles [c. 6.4 km] SW Stapleton Railway Siding, *Muspratt 104*, 4 Mar 1963 (DNA, MEL, NSW); 40 miles [c. 64 km] E Pine Creek, *Byrnes 1342*, 29 Jan 1969 (DNA); 2 km E of Bark Hut, *Cowie 1377 & Booth*, 8 Feb 1991 (NSW); near Truant Island lighthouse, *Mitchell 6751*, 26 Apr 2001 (CANB, DNA, NSW).

Indigofera trifoliata L., Cent. Pl. 2: 29 (1756)

Lectotype (see Sanjappa in Turland and Jarvis 1997: 474): India, Herb. Linn. 923.3, right-hand plant (LINN, photo seen)

Anila trifoliata (L.) Kuntze, Rev. Gen. Pl. 2: 940 (1891)

Illustration: Banks and Solander (1900) t. 56.

Erect or spreading, rarely prostrate or trailing, perennial herb or subshrub, 0.3–0.6(–1.2) m high, with woody rootstock or taproot; young stems ridged, green, strigose with dense, appressed, equally or unequally biramous hairs. Leaves digitately trifoliolate, very rarely 5-foliolate; stipules linear, 0.6–0.9 mm long, pubescent, not spinescent, not persistent; petiole 5–14 mm long; rachis furrowed; multicellular hairs between leaflet pairs sparse, inconspicuous, orange to red or brown, pointed-linear. Leaflets opposite; stipellae inconspicuous, 0.2–0.5 mm long; lamina obovate often narrow and elliptical to oblanceolate, (7–)12–30(–37) mm long, (2–)2.5–8.5(–11.5) mm wide; upper surface green, with sparse, appressed or shortly spreading hairs; lower surface green, with sparse, appressed hairs and conspicuous, yellow discoid glands; apex obtuse or acute and shortly mucronate; veins not prominent. Inflorescences 3.5–8(–13.5) mm long, shorter than leaves; peduncle 0–0.5 mm long; bracts ovate, 0.3–0.6 mm long; flowers red; pedicel 0.4–0.9 mm long. Calyx 1.5–2.6 mm long; lobes subequal, longer than the length of the tube and covered with moderately dense, white to pale brown, appressed hairs. Standard red, ovate to obovate, 3.3–5 mm long, 2.4–3.4 mm wide. Wings ± glabrous, 3.3–5 mm long, 1.1–1.8 mm wide. Keel 3.7–5 mm long, 1.4–1.7 mm deep; lateral pockets 0.7–1.3 mm long; apex acute or rounded; hairs moderately dense, hyaline or brown, at the tip and along the bottom, interspersed with numerous discoid glands; margin ciliate. Staminal tube (2.2–)2.7–3.3 mm long, colourless. Ovary moderately hairy; discoid glands present on the ventral surface; style long, to c. 2.5 mm. Pod descending, terete, with four narrow wings (one on either side of each suture), (5–)7–15(–20) mm long, 1–1.5 mm wide, brown, glabrescent, or strigose; hairs sparse, appressed (discoid glands also present); apex shortly beaked; endocarp not spotted; seeds 3–7 per fruit.

Notes: Endo and Ohashi (1998) found that *I. trifoliata* can be readily divided into two groups based on staminal tube length (1.7–3.2 mm vs. 4.0–6.0 mm) and style length (0.6–2.9 mm vs. 3.3–5.3 mm) with very few intermediates. These authors did not, however, examine the type specimen. Staminal tubes and styles on the type specimen have been measured and found to be long (c. 4.5–5 and c. 4 mm long respectively), so populations in Australia do not match the type in this respect.

For other synonyms of *I. trifoliata* sens. lat., see de Kort and Thijsse (1984) and Endo and Ohashi (1998).

Distribution and habitat: Queensland, Northern Territory, and Western Australia; it is found in woodland, open forest or grassland. It is recorded from a range of substrates: gravelly or clay loams, black soil flats, river alluvium, skeletal soils on sandstone, and metamorphic or lateritic hill slopes. Outside Australia, the species is recorded from Pakistan to South China, Malesia and New Guinea.

Judging from the specimens seen, this species is now less widespread in Australia than it was in the late nineteenth and early twentieth centuries. This is particularly true for the subtropical part of its recorded range; there have been few recent records for many of the more southern regions of Queensland.

Selected specimens: Queensland: Burke: Sweers Island, *Henne s.n.* (MEL 586300). Burnett: Mount Perry, *Keys s.n.* (BRI 233639). Cook: Thursday Island, on road up Green Hill, *Clarkson 6368*, 8 Apr 1986 (BRI); 12.6 km SE of Mt Janet on the survey road along the Great Dividing Range, 11.5 km SW of Lakeland Downs township, *Clarkson 5954*, 4 June 1985 (BRI, MEL, NSW); 2.2 km SW of Archer Creek on the Ravenshoe to Mount Garnet road, *Clarkson 3661*, 17 Mar 1981 (BRI, NSW). Moreton: Goodna, *Simmonds s.n.*, 27 Apr 1889 (BRI 233643). North Kennedy: Cashmere, *Armit 156*, 20 Mar 1875 (MEL 586620); Burdekin River area above Dalbeg on track to Gorge Weir, 20.9 km S of Expedition Pass Creek bridge, *Staples 2116*, 16 Apr 1975 (BRI, CANB); Ayr, *Blake 8332*, 28 Mar 1935 (BRI, CANB). Port Curtis: Nagoorin, Boyne Valley Line, *Kahler s.n.*, 21 Oct 1935 (BRI 233646); South Percy Island, *Tryon s.n.*, 5 Mar 1906 (BRI 233645). South Kennedy: Calen, *Preller s.n.*, 21 Jan 1935 (BRI 233650). Wide Bay: State Forest 50, Glenbar, 3 km WSW of Mt Urah summit, *Forster 13121 & Machin*, 27 Feb 1993 (BRI, NSW, MEL). **Western Australia**: Gardner: Mitchell Falls track, *Wilson 313 & Jacobs*, 31 May 1988 (NSW, PERTH, L); King-ana, S end of Vansittart Bay, *Mitchell 2899*, 24 Mar 1993 (NSW); Careening Bay, Port Nelson, *Kenneally 10067*, 30 May 1987 (PERTH). **Northern Territory**: Darwin & Gulf: Dalywoi Bay, Gove, *Russell-Smith 4666*,10 Feb 1988 (DNA); Kapalga, *Dunlop 6068 & Taylor*, 9 Mar 1982 (NSW); Coomalie Creek, c. 40 miles [64 km] SE of Darwin, *Muspratt 208*, 18 Jan 1963 (DNA, BRI, NSW); Cobourg Peninsula, Trepang Bay, *Cowie 3636*, 18 Apr 1993 (BRI, CANB, NSW, PERTH); Fossil Head, *Leach 4215*, 23 Feb 1994 (NSW).

Indigofera trita L.f., Suppl. 335 (1782) subsp. ***trita***

Holotype: 'Habitat in India' (LINN 923.9, photo seen)

Anila trita (L.f.) Kuntze, Rev. Gen. Pl. 2: 940 (1891)

I. timorensis DC., Prod. 2 : 223 (1825)

Type Citation: '? in ins. Timor' (holo G-DC, *n.v.*; NSW microfiche)

Erect, annual or short lived perennial herb, 0.15–0.45 m high, with taproot; young stems ridged, green to grey, strigose with moderately dense to dense, appressed, equally biramous hairs. Leaves trifoliolate; stipules linear or narrow and triangular, (1.0–)1.5–3 mm long, pubescent, not spinescent, generally not persistent; petiole (1.5–)4–10(–15) mm long; rachis furrowed; multicellular hairs between leaflet pairs absent or sparse (only 2–3), inconspicuous, orange, pointed-linear; stipellae absent; lamina elliptical to obovate, (5–)8–20(–25) mm long, (2.0–)2.5–7(–10) mm wide; upper and lower surface green to grey, with moderately dense (rarely sparse) appressed hairs; apex obtuse and shortly or inconspicuously mucronate; veins not prominent. Inflorescence (5–)10–35(–50) mm long, shorter than to longer than leaf; peduncle 0.5–3(–5.0) mm long; bracts narrowly ovate, 0.5–1.5 mm long. Flowers dull or pale red; pedicel 0.5–1 mm long; calyx 2.5–5 mm long; lobes subequal, longer to much longer than the length of the tube and covered with moderately dense, grey, appressed hairs; standard red, elliptical to obovate, 5–6 mm long, 3.5–4.5 mm wide; wing narrowly obovate to spathulate, 5–6 mm long, 1.5–2.3 mm wide; keel 5–5.7 mm long, 1.5–2 mm wide, with lateral pockets 0.5–0.9 mm long, rounded apex, and sparse, hyaline or white hairs along the bottom; staminal tube 3–4 mm long, colourless; ovary sparsely or moderately hairy (becoming dense when fruit young). Pod spreading to descending, the pedicel strongly down-turned and the fruit standing out at a pronounced angle, terete with a longitudinal ridge along each side of the pod, giving a 4-angled appearance, (8–)20–30 mm long, 2–3 mm wide, yellowish to pale brown, strigose; hairs moderately dense, appressed; apex shortly beaked or pointed; endocarp not spotted; seeds (2–)8–10 per fruit.

Notes: stipellae are apparently absent, although the 1–2 multicellular hairs recorded here may be much reduced stipellae that are up to 0.1 mm long only.

See Wilson & Rowe (1994) for specimen citations and discussion of variation in *Indigofera trita* sens. lat. See de Kort and Thijsse (1984) for full synonymy.

Distribution and habitat: Queensland, Northern Territory, and Western Australia (see Wilson & Rowe 1994: fig. 1); it is found in a wide range of habitats: cracking clay, rich loamy or sandy soils on open plains or amongst rocks of various types on hills. Also found in Pakistan, India, Sri Lanka, Burma & Indonesia.

Species with alternate leaflets

The species with alternate leaflets also fall into two groups morphologically. The first group, of two species, is characterised by having short pods that rarely exceed 10 mm in length. These species also lack endocarp spots. They are currently placed in section *Brachycarpae* Wight & Arn. This section also includes the simple-leaved species *I. linifolia* and *I. cordifolia*. The second set, of four species, can show other features similar to those in the first two species, particularly scarious stipule margins, and two of them also lack endocarp spots. These four species have been classified in section *Alternifoliolae* Harv.

Key to species with alternately pinnate leaves

1 Pod short, usually <10 mm long; seeds 2–4 2
1 Pod 10–30 mm long; seeds 4–8 3

2 Sepals distinctly fused at base, to 0.5 mm wide; seeds usually 2; keel 3.5–4.5 mm long; staminal tube 2.5–3.2 mm long .... ***I. linnaei***
2 Sepals only slightly fused at base, to 0.2 mm wide; seeds 2–4; keel 2.7–3.0 mm long; staminal tube 1.5–1.8 mm long .... ***I. sessiliflora***

3 Pods straight 4
3 Pods curved or coiled 5

4 Pod 22–27 mm long (including a distinct beak 1.5–2.5 mm long); inflorescence over 120 mm long; leaflets 7–10, obovate to elliptical; staminal tube 3.5–4.0 mm long .... ***I. hendecaphylla***
4 Pod 10–18 mm long with a short, blunt tip 0.5 mm long; inflorescence to 80 mm long; leaflets 5–7, obovate; staminal tube 2.3–3.2 mm long .... ***I. spicata***

5 Plants erect; leaflets 1–4, 10–18 mm long; pods curved .... ***I. oblongifolia***
5 Plants prostrate; leaflets 4–7, 3.5–9.5 mm long; pods coiled .... ***I. circinella***

****Indigofera circinella*** Baker f., J. Bot. 44: 314 (1906)

Holotype: Kenya: *Scott Elliot 6892* (BM, *n.v.*). Isotype: K, *n.v.*

Prostrate perennial herb, less than 5 cm high, branches to 50 cm long or more, with taproot; young stems ridged or flattened, pale green, pubescent with sparse, appressed, equally biramous hairs plus some multicellular hairs. Leaves pinnate, (4–)6(–7)-leaflets; stipules triangular, 1.5–2.5 mm long, with scarious margin and narrow, red-brown, club-shaped multicellular hairs, glabrescent, not spinescent, persistent; petiole 0.5–1 mm long; rachis furrowed; multicellular hairs at the base of the petiolule sparse, inconspicuous, red to brown, club-shaped. Leaflets alternate, stipellae absent; lamina cuneate or obovate, 3–10 mm long, 1.5–3.5 mm wide; upper surface green, glabrous; lower surface green, with sparse, appressed hairs; apex obtuse and mucronate; veins not prominent. Inflorescences 4–10 mm long, shorter than leaves; peduncle 1–2 mm long; bracts ovate, 1 mm long; flowers pink to orange-red; pedicel 0.5–1 mm long. Calyx 2.5–3 mm long; lobes subequal to equal, longer than the length of the tube and covered with moderately dense, white appressed hairs. Standard pink, broadly obovate, 2.5–3 mm long, 2.5–3 mm wide. Wings spathulate, 3 mm long, 0.5–1 mm wide. Keel 2.5–3.5 mm long, 1 mm deep; lateral pockets 0.3–0.5 mm long; apex acute; glabrous or with very occasional hyaline to white hairs at the tip. Staminal tube 2–2.5 mm long, colourless. Ovary densely hairy. Pod deflexed, circinate and somewhat torulose, 15–25 mm long, 1.5–2 mm wide, brown, pubescent; hairs sparse to moderately dense, appressed; apex upturned and shortly beaked with persistent style; endocarp with pale orange spots. Seeds 6–14 per fruit.

Distribution: Queensland; recently naturalised in Brisbane. Native of Africa.

Selected Specimens: Queensland: Moreton: Coorparoo [suburb of Brisbane], *Guymer 1873 & Sharpe*, 17 Feb 1984 (BRI, CANB, MEL, NSW); Chapel Hill Reservoir, Fleming Road, *Bean 12762*, 14 Dec 1997 (BRI, NSW).

***Indigofera hendecaphylla** Jacq., Coll. Bot. 2: 358 (1788)

Indigofera endecaphylla auctt., orth. var.

Holotype: West Africa: 'Guinea', cultivated Vienna. (W, *fide* Du Puy et al. 1993)

Indigofera spicata auctt.

Illustration: Morton (1989) figs 1–3, as *I. spicata*; Du Puy et al. (1993) Fig. 1, F–K.

Spreading, perennial herb or subshrub, (0.2–) 0.4–0.6 m high, with taproot; young stems ± flattened and ridged, green or yellowish, strigose with sparse, hyaline to white, appressed, equally biramous hairs. Leaves pinnate, 7–10 leaflets, 20–55 mm long; stipules triangular with scarious margins, 5–7.5 mm long, glabrescent, not spinescent, persistent; petiole 1.5–5 mm long; rachis furrowed; multicellular hairs at the base of the petiolule absent. Leaflets alternate; stipellae absent or inconspicuous, 0.2–0.6 mm long, hair-like; lamina obovate to elliptical, 5–16 mm long, 2.5–7 mm wide; upper surface dull green, glabrous; lower surface green, with sparse to moderately dense, appressed hairs; apex obtuse and mucronate; veins not prominent. Inflorescences 120–150 mm long, longer than leaves; peduncle 10–20(–25) mm long; bracts ovate to triangular (margin scarious), 1.2–2.5 mm long; flowers red; pedicel 0.3–0.7 mm long. Calyx 2.5–4 mm long; lobes longer than the length of the tube, subequal, 1.5–3 mm long and covered with moderately dense, white, appressed hairs. Standard red, obovate, 3.8–4.9 mm long, 2.5–3.7 mm wide; hairs sparse to moderately dense, hyaline to white; apex obtuse. Wing oblong to spathulate, 3.7–4.5 mm long, 0.5–1.1 mm wide. Keel 3.9–4.4 mm long, 1–1.3 mm deep; lateral pockets 0.3–0.5 mm long; apex rounded; glabrous or with sparse, hyaline hairs; margin ciliate. Staminal tube 3.5–4 mm long, colourless. Ovary moderately to densely hairy. Pod descending, terete to slightly tetragonal, 22–27 mm long, 2.2–2.5 mm wide, brown, strigose, glabrescent; hairs sparse, appressed; apex shortly beaked (beak 1.5–2.5 mm long); endocarp not spotted; seeds cuboid, 7–10 per fruit, 1.3–1.6 mm long, 1–1.4 mm wide.

Notes: this species was for a long time considered a synonym of *I. spicata* until Du Puy et al. (1993) clarified the distinctions between the two species. Of the two, this appears to be the species definitely implicated in stock poisoning. The description given by Morton (1989) is certainly of this species, which was responsible for 'Grove Poisoning' of horses in Florida. Everist (1974) gives a full account of the occurrences of poisoning in Australia and of the toxic principle, indospicine, an analogue of the amino acid arginine. *I. spicata* is also naturalised in Australia (see below). References to *I. spicata* as a weed in Australia (Lazarides et al. 1997) would apply to this species as well.

See Du Puy et al. (1993) for full synonymy.

Distribution and habitat: only recorded from north Queensland, on the Atherton Tableland, from disturbed sites. The natural range of the species is Africa to Asia, but it is also naturalised in the West Indies, the southern United States and South America.

Selected Specimen: Queensland: Cook: Ball Rd, Malanda, *Doherty s.n.*, 28 July 1965 (BRI).

Indigofera linnaei Ali, Bot. Not. 111: 549 (1958)

Hedysarum prostratum L., Syst. Nat., ed 12, 2: 496 (1767); Mant. 1: 102 (1767)

Lectotype (see Rudd 1991: 120): Burman, Fl. Indica, 168, t. 55, f. 1 (1768)

Anila prostrata (L.) Kuntze, Rev. Gen. Pl. 2: 938 (1891)

Indigofera prostrata (L.) Domin, Biblioth. Bot. 89: 187 (1926) *nom. illeg.* non Willd. (1805) nec DC. (1825) nec Roxb. (1832) nec Wight & Arn. (1834)

Indigofera enneaphylla L., Mant. 2: 272 (1771) *nom. illeg.* (see Ali 1958: 551)

I. dominii Eichler, Fl. S. Austral., ed. 2, suppl. 190 (1965) *nom. superfl.*

Illustration: Gardner and Bennetts (1956) plate xliii, as *I. enneaphylla*; Everist (1974) plate 25; Cunningham et al. (1981: 398) photo, as *I. dominii*; Jessop and Toelken (1986) fig. 309B; Urban (1990: 96) photo; Hacker (1990: 183) photo; Anderson (1993: 166) photo; Milson (1996: 49) photo.

Prostrate to spreading, perennial herb, 0.05–0.3 m high, to 0.7 m wide, with taproot; young stems slightly ridged (becoming obvious on older stems), green to white, strigose to pubescent with dense, appressed to spreading, equally biramous hairs. Leaves pinnate, (5–)7–9(–13) leaflets; stipules triangular with linear, drawn-out tip and thin scarious margin, (2–)3–7 mm long, pubescent, not spinescent, often persistent; petiole 1–4 mm long; rachis furrowed or flattened; multicellular hairs at the base of the petiolule absent. Leaflets mostly alternate; stipellae absent or very inconspicuous, 0.1–0.5 mm long; lamina obovate, (4.5–)5–15(–23) mm long, (1.0–)1.5–7(–10) mm wide; upper surface green to grey, with sparse to dense, appressed to spreading hairs; lower surface green to grey, with moderately dense to dense, appressed to spreading hairs; apex obtuse and mucronate, emarginate or rarely acute; veins not prominent. Inflorescences (3–)5–20(–35) mm long, generally shorter than the leaf; peduncle 0.5–2(–13) mm long; bracts ovate to triangular, 1.5–3.5 mm long, with scarious margins; flowers red; pedicel 0.5 mm long. Calyx 2.5–5 mm long; lobes unequal or subequal, longer than the length of the tube, covered with moderately dense to dense, grey, white or pale brown, appressed to shortly spreading, very unequal biramous hairs. Standard red, obovate, 3–5 mm long, 2.3–3.3 mm wide. Wings oblong to spathulate, 3.5–5 mm long, 0.7–1.2 mm wide. Keel 3.5–4.5 mm long, 0.7–1.2 mm deep; lateral pockets 0.3–0.6 mm long; apex beaked to acute; glabrous. Staminal tube (2.0–)2.5–3.2 mm long, colourless. Ovary densely hairy. Pod ascending, shortly cylindrical, (2.5–)4–8(–10.5) mm long, 2–2.5 mm wide, white to grey or yellowish and brown, strigose to pubescent; hairs moderately dense to dense, appressed to spreading; apex shortly pointed; endocarp not spotted; seeds (1–)2(–4) per fruit.

Notes: this plant is usually ± prostrate but, as pointed out by Gardner and Bennetts (1956), it is occasionally found with erect stems up to 45 cm high. They cite a record from near Halls Creek. In the present study, the first author found erect plants at only one location, also in the Kimberley region (*Wilson 209*). Seed number is almost always 2; the single, undated collection with about 4 seeds per fruit seems to have been collected in the late 19th Century at Peak Downs (*Burkitt s.n.* MEL586548, 586552).

Gardner and Bennetts (1956) and Everist (1974) give a detailed account of the toxicity of this species, which causes 'Birdsville Disease' in horses, the symptoms of which include weight loss, general weakness and progressive loss of coordination. The causative agent for this disease is uncertain but it is known that *I. linnaei*, like *I.* spicata, produces indospicine and this may interfere with utilisation of arginine by the animal. Although indospicine is a known hepatotoxin and accumulates in the liver of horses, it does not produce liver disease but it is known to cause liver necrosis in dogs fed on horse meat (Pollitt et al. 1999).

Distribution and habitat: Queensland, New South Wales, South Australia, Western Australia, and the Northern Territory. Recorded as growing on most substrates, particularly on sand in open areas, grassland or woodland, and particularly on disturbed sites like roadsides. Also found in Pakistan, India, Sri Lanka, Burma, Thailand, Vietnam, Indonesia and New Guinea. *Indigofera linnaei* is considered a weed in Australia (Lazarides et al. 1997).

Selected specimens: Queensland: Burke: 20 miles [c. 32 km] SW of Cloncurry township, *Lazarides 4407*, 16 Mar 1954 (AD, BRI, CANB, DNA, MEL). Burnett: 'Brian Pastures', Gayndah, *McKee 10205*, 3 Apr 1963 (BRI, NSW). Cook: 7 km from Kennedy crossing on Fairview–Kimba road on track to King River outstation, *Clarkson 3239*, 22 Apr 1980 (BRI, NSW). Gregory North: Carrandotta, *Everist 3285*, 27 Nov 1947 (BRI). Gregory South: South Galway Station, 60 miles [c. 96 km] SW of Windorah, *Everist 4117*, 7 Sep 1949 (BRI, DNA). Leichhardt: Orion Downs, *Everist 4345*, 20 June 1951 (BRI, CANB). Mitchell: 8.9 km S of Jundah turn-off on 'Warbreccan'–Windorah road, *Wilson 396 & Pickering*, 22 Sep 1989 (NSW). Moreton: near Laidley, *Blake 10407*, 26 Jan 1936 (BRI, CANB). North Kennedy: Cardington, c. 40 miles [c. 64 km] S of Townsville, bank of Haughton River, *Everist 5515*, 11 May 1954 (BRI, CANB). Port Curtis: Apis Creek, Bruce Highway, 40 km W of Marlborough, *Halliday 358*, 5 Apr 1975 (BRI). South Kennedy: 8 km SE of Eungella Dam, *Byrnes 3615 & Clarkson*, 6 Apr 1978 (BRI). Warrego: 22 km N of Charleville along road to Augathella, *Purdie 186 & Boyland*, 25 Mar 1976 (BRI). Wide Bay: Mt Walsh, 6 km S of Biggenden, *Crisp 2588 & Ellyard*, 28 May 1977 (BRI, DNA). **New South Wales**: North Coast: Copmanhurst, *Rupp 2*, Feb 1910 (NSW). North Far Western Plains: Berawinnia Downs, *Milthorpe 5069 & Cunningham*, 30 Nov 1976 (NSW). North Western Plains: MacIntyre River, Yetman, *Dunn 65, Plat & Coveny*, 28 Mar 1987 (NSW, BRI). **South Australia**: North-western: Ernabella Mission, *Turvey s.n.*, 8 May 1963 (AD, DNA, NSW). Lake Eyre: Birdsville Track, near Mt Gason, c. 45 km SSW of Clifton Hills homestead, *Crisp 39 & Noble*, 6 Apr 1969 (AD); Wintinna Creek, between Coober Pedy and Welbourn Hill, *Beauglehole 44369*, 21 May 1974 (MEL). **Western Australia**: Carnarvon: 1 mile [c. 1.6 km] E of Yanrey HS, turn-off to Bullara, *George 1175*, 29 Aug 1960 (PERTH). Dampier: 4 km S of Cape Bertholet, Dampierland, *Kenneally 6024*, 19 Apr 1977 (CANB, PERTH). Fitzgerald: 3.7 km E of Fletcher River crossing, Gibb River Road, *Wilson 209*, 10 May 1988 (NSW, PERTH, B, K). Fortescue: 8.1 km WNW of East Harding River, North West Coastal Highway, *Wilson 1006, Rowe & Mitchell*, 10 Sep 1991 (NSW, PERTH, PRE). Gardner: Osmond Creek below junction with Red Rock Creek, Bungle Bungle NP, *Menkhorst 911*, 21 June 1989 (DNA). Hall: Duncan Highway, 134 km E of Halls Creek, *Beauglehole 51231*, 22 May 1976 (PERTH). Keartland: Rudall River, *George 10644*, 18 May 1971 (CANB, PERTH). **Northern Territory**: Barkly Tableland: 9 miles [c. 14.4 km] W of Alroy Downs, *Chippendale NT 5372*, 8 Mar 1959 (AD, BRI, CANB, DNA, NSW); Lorne Ck, 16 miles [25.6 km] N of Soudan, *Chippendale NT 1851*, 18 Mar 1956 (BRI, DNA, MEL, NSW). Central North: 20.8 miles [c. 33.7 km] N of Georgina Downs homestead, *Chippendale NT 3821*, 1 Oct 1957 (AD, DNA, NSW); Singleton, 240 miles [c. 384 km] N of Alice Springs, *Everist 4234*, 28 Jan 1950 (BRI, DNA. MEL). Central South: Kings Canyon, *Latz 262*, 10 Dec 1968 (DNA, NSW, K, MO); Blue Grass Bore, 15 miles [c. 24 km] SW Milton Park homestead, *Nelson NT 11961*, 23 Feb 1966 (AD, BRI, DNA, NSW). Darwin & Gulf: 58 miles [c. 93 km] NE of Beetaloo homestead, *Chippendale NT 5497*, 10 Mar 1959 (AD, BRI, DNA). Victoria River: 13 miles [c. 20.8 km] N Montejinni homestead, *Chippendale NT 6923*, 11 May 1960 (BRI, DNA, NSW).

****Indigofera oblongifolia*** Forssk., Fl. Aegypt. Arab. 137 (1775)

Type: [Yemen] Lohajae, *Forsskål s.n.* (not extant, fide Hepper & Friis 1994)

Neotype (see Ali 1958:546): Aegyptus superior, *E. Boissier*, Feb. 1846 (K, *n.v.*)

Illustration: Andrews (1952) fig. 81.

Erect shrub, 0.5–2 m high, with woody rootstock; young stems ridged, grey to green, strigose with dense to very dense, appressed, equally biramous hairs. Leaves variable, with 1–3(–4) leaflets, unifoliolate, trifoliolate, or pinnate; stipules narrowly triangular, 2–6 mm long, pubescent, not spinescent, not persistent; petiole 2–6(–10) mm long; rachis furrowed; multicellular hairs at base of leaflets sparse, inconspicuous, pale orange, pointed-linear. Leaflets alternate; stipellae absent or inconspicuous and 0.2–0.5 mm long; lamina of lateral leaflets elliptical to obovate, (8–)10–18 mm long, 3.5–6 mm wide; terminal or unifoliolate leaflets elliptical or obovate, 15–30 mm long, 5–9 mm wide; upper surface grey to green, with sparse to moderately dense, appressed hairs; lower surface grey to green, generally paler than above, with moderately dense, appressed hairs; apex acute or obtuse and mucronate; veins not prominent. Inflorescences (15–)30–105 mm long, longer than leaves; peduncle 3–7 mm long; bracts ovate, 1 mm long; flowers red, the colour variable with pink and yellow-green shades; pedicel mostly 0.7–0.9 mm long. Calyx 1.5–2.5 mm long; lobes equal or unequal, less than to longer than the length of the tube and covered with moderately dense to dense, grey, appressed hairs. Standard with red striations, ovate to obovate, 5–6 mm long, 4–4.5 mm wide. Wings pink-red, spathulate to narrowly obovate; 4.5–5 mm long, 1.5–2 mm wide. Keel greenish but flushed pink in the upper part, 4.5–6.5 mm long, 1.5–2 mm deep; lateral pockets 1–1.3 mm long; apex acute to rounded; glabrous to sparsely hairy with hyaline to grey hairs at the tip and along the bottom; margin variably ciliate. Staminal tube 4–5 mm long, colourless. Ovary moderately to densely hairy. Pod spreading to deflexed, terete and torulose, crescent shaped, (6–)10–19 mm long, 2 mm wide, brown, strigose; hairs moderately dense, appressed; apex acute or shortly beaked; endocarp not spotted; seeds (1–)4–6 per fruit.

Notes: see de Kort and Thijsse (1984) for full synonymy. These authors, and a few others, suggest that the type of this species is amongst Forsskål's collections at Copenhagen but Hepper and Friis (1994) assert that a Forsskål specimen of this species cannot be found there. Further enquiries at Copenhagen have confirmed that no Forsskål material of this species has been found since 1994 (Olof Ryding pers. comm. 2007). Ali (1958) designated a neotype.

Distribution and habitat: the natural range of this species is from northern tropical Africa to northern India and Sri Lanka; it is also recorded from Java where it is probably introduced. It has become naturalised in the vicinity of Port Hedland and De Grey Station in the Fortescue region of Western Australia where it occurs in gravelly and sandy alluvial soils. Label information with the most recent collection indicates that this species is actively spreading and is abundant on roadsides and in disturbed areas.

Selected Specimens: Western Australia: Fortescue: Along main road between Port Hedland & South Hedland, *Mitchell 2451*, 25 Apr 1992 (NSW); c. 18 km S of De Grey Homestead on main road on W side of river, *Mitchell 3566*, 27 Apr 1994 (NSW, PERTH); De Grey River on Northern Coastal Highway, *Allen s.n.*, 2 Aug 2007 (BRI, NSW).

****Indigofera sessiliflora*** DC., Prod. 2: 228 (1825)

Holotype: Senegal, *Perrottet s.n.* (P, *n.v.*). Isotype: BM, *n.v.*

Anila sessiliflora (DC.) Kuntze, Rev. Gen. Pl. 2: 940 (1891)

Spreading or prostrate, annual or short lived perennial herb, 0.05–0.15 m high, with taproot; young stems ridged, green, hirsute with dense, somewhat spreading, equally or unequally biramous hairs. Leaves pinnate, 3–7 leaflets; stipules triangular, 2.5–5 mm long, pubescent, not spinescent, not persistent; petiole 4–7 mm long; rachis furrowed; multicellular hairs at the base of the petiolule absent. Leaflets alternate or sub-opposite; stipellae absent; lateral leaflets elliptical to obovate, 5–16 mm long, 2.5–6 mm wide; upper and lower surface green to grey, with sparse to moderately dense, appressed to shortly spreading hairs; apex acute or obtuse and mucronate; veins not prominent. Inflorescences 5–13 mm long, shorter than leaves; peduncle 0–1 mm long; bracts narrowly triangular, 0.8–1.2 mm long; flowers red; pedicel 0–0.5 mm long. Calyx 2.5–3.5 mm long; lobes equal, much longer than the length of the tube and covered with moderately dense to dense, grey, shortly spreading hairs. Standard red, obovate, 2.5–3 mm long, 1.3–1.9 mm wide. Wings oblong to narrowly obovate, 2.5–2.8 mm long, 0.6 mm wide. Keel 2.7–3 mm long, 0.8–0.9 mm deep; lateral pockets 0.3–0.5 mm long; apex acute; glabrous. Staminal tube 1.5–1.8 mm long, colourless. Ovary moderately hairy. Pod ascending, shortly cylindrical and slightly torulose, 3–7 mm long, 1.5 mm wide, grey to pale brown, strigose; hairs sparse to moderately dense, appressed to shortly spreading; apex shortly pointed; endocarp not spotted; seeds ± spherical, 2–4 per fruit.

Distribution and habitat: only recorded from Western Australia where it appears to be a relatively recent introduction, perhaps from a ship's ballast. This species is naturalised at Port Hedland where it has been found along the foreshore and on road edges on sandy soils; it has the potential to become a serious weed. It is native to western and north-eastern Africa, through Saudi Arabia to Pakistan and north-western India.

Other specimens examined: Western Australia: Fortescue: Spoil Bank Recreation Area, *Wilson 1001 & Rowe*, 8 Sep 1991 (NSW, CANB, K, KARR, PERTH, UPS); between foreshore and main road opposite Port Hedland hospital, *Mitchell 2452*, 25 Apr 1992 (NSW, PERTH).

****Indigofera spicata*** Forssk., Fl. Aegypt. Arab. 138 (1775)

Holotype: [Yemen] Bolgose, *Forsskål 1356*, March 1763 (C, *fide* Hepper and Friis 1994)

Anila ? *spicata* (Forssk.) Kuntze, Rev. Gen. Pl. 2: 940 (1891)

Illustration: Hacker (1990: 186) photo; Du Puy et al. (1993) Fig. 1, A–E.

Prostrate perennial herb, up to 0.5 m high, with woody rootstock; young stems ridged (flattened when young), green or yellowish, strigose with sparse, hyaline to white appressed, equally biramous hairs. Leaves pinnate, 5–7 leaflets, 12–40 mm long; stipules triangular with scarious margins, (2.5–)3.5–5.5(–6.5) mm long, glabrescent, not spinescent, persistent; petiole 2–6 mm long; rachis furrowed; multicellular hairs at the base of the petiolule absent. Leaflets alternate; stipellae absent or inconspicuous, 0.2–1.2 mm long, membranous, some dividing into 2 or 3 segments; leaflets obovate, (3–)4–11(–16) mm long, 2.5–8(–10) mm wide; upper surface dull green, glabrous or with sparse, appressed hairs; lower surface green with sparse to moderately dense, appressed hairs; apex obtuse (with a short mucro); veins not prominent. Inflorescences 30–65(–80) mm long, longer than leaves; peduncle 15–20(–25) mm long; bracts triangular (margin scarious), 1.2–2 mm long; flowers pink to orange-red; pedicel 0.3–0.7 mm long. Calyx 2–3 mm long; lobes subequal, longer than the length of the tube and covered with sparse to moderately dense, white, appressed hairs. Standard reddish, obovate, 3.8–4.9 mm long, 2.5–3.7 mm wide; hairs sparse (few at apex only), hyaline to white; apex obtuse. Wing oblong to spathulate, 3.7–4.5 mm long, 0.5–1.1 mm wide. Keel 3.9–4.4 mm long, 1–1.3 mm deep; lateral pockets 0.3–0.5 mm long; apex acute; glabrous or with sparse, hyaline hairs at the tip. Staminal tube 2.3–3.2 mm long, colourless. Ovary moderately to densely hairy. Pod descending, terete (often torulose when young), 10–18 mm long, 1.5–2 mm wide, yellowish and brown, strigose to glabrescent; hairs sparse, appressed; apex shortly pointed (to 0.5 mm long); endocarp not spotted; seeds cuboid, 4–8 per fruit, 1.3–1.6 mm long, 1–1.4 mm wide.

Notes: see Du Puy et al. (1993) for full synonymy. As far as we can determine, this species has not definitely been implicated in stock poisoning, all documented occurrences apparently referring to *I. hendecaphylla*.

Distribution and habitat: this species is a native of Africa but has been recorded as naturalised in a few areas of southern Queensland, near Coffs Harbour in northern New South Wales, and in Katherine, Northern Territory, where it occurs in open, disturbed areas. Some of these plants may be descended from plants grown in field trials as a potential fodder species.

Selected specimens: Queensland: Moreton: St Lucia, Brisbane, *Pedley 5372*, 3 May 1987 (BRI, MEL, NSW). Wide Bay: old North Deep Creek pasture site, Widgee Shire, *Cook s.n.*, 16 Jan 1980 (BRI). **New South Wales**: North Coast: Mid Sapphire Beach, N of Coffs Harbour, *Benwell s.n.*, Feb 2005 (NSW). **Northern Territory**: Katherine Research Station, *Mitchell 6384*, 16 Oct 2000 (NSW).

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Typification of some names in *Eucalyptus* (Myrtaceae), Part 1

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Abstract

Eleven names in *Eucalyptus* are newly typified, and the typification is clarified for a further four names. The species involved are all indigenous to Queensland or New South Wales. Full discussion of relevant type specimens is provided, and other nomenclatural notes are included. Information provided in recent nomenclatural references for eucalypts is discussed, especially where the conclusions differ from the views expressed here.

Introduction

There remain significant numbers of accepted *Eucalyptus* species names that have never been formally typified. This paper clarifies the typification for 15 names in *Eucalyptus*, including eleven names that are newly typified. Nomenclatural information offered by Brooker et al. (1984), Chippendale (1988), Hill (2002–04) and Slee et al. (2006) are discussed, especially where it is inconsistent or differs from the current view. Some miscellaneous errors from these publications are also brought to notice.

The Articles referred to in this paper e.g. Article 9.5, are all from the latest version of the International Code for Botanical Nomenclature (McNeill et al. 2006).

The species are arranged alphabetically by currently accepted name.

Typification

Eucalyptus argophloia Blakely, Key Eucalypts 256 (1934).

Type: Queensland. 12 miles N of Chinchilla, *R.C. Beasley s.n.*, May 1933 (**lecto** NSW [NSW40185], here designated; isolecto BRI [AQ094179]; K [K000347651]).

The protologue says "between 6 and 7 miles north of Chinchilla; 1 mile east of Branch Creek, Burncluith, about 12 miles north of Chinchilla. It is more plentiful in the latter locality (R.C. Beasley, April and May 1933)".

There are two known gatherings by Beasley that correspond to the citation in the protologue. One has a label saying "12 miles N of Chinchilla, May 1933". Specimens from this gathering are present at NSW, BRI and K. The sheet at NSW is here chosen

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as the lectotype. It has pressed but unmounted branchlets bearing juvenile leaves, adult leaves, mature buds and flowers. There are some mature fruits in a packet.

Specimens from the second gathering are present at BRI and K. They have a Queensland Herbarium label saying "Chinchilla, April 1933, R.C. Beasley" and bear the same range of material.

Eucalyptus bridgesiana R.T.Baker, Proc. Linn. Soc. New South Wales 23: 164 (1898).

Type: New South Wales. Albury, *Andrews s.n.*, 21 June 1897 (**lecto** NSW [NSW314589], here designated).

The protologue states "Hab. - VICTORIA: Gippsland ('But But,' 'Apple- tree,' 'Apple-tree Box,' 'White Box,' A. W. Howitt, F.G.S.). N.S.WALES: Colombo ('Apple-top Box,' W. Baeuerlen); Albury ('Apple,' Dr. Andrews); Gerogery ('Woolly-butt,' J. Manns); Rylstone ('Woolly-butt,' R.T.B.); Bathurst ('Bastard Box,' W. Woolls)."

The Gerogery and Bathurst specimens are apparently no longer extant; the Colombo specimen does not match the protologue and belongs to a different species (*E. angophoroides*); the Rylstone collection is of poor quality with immature fruits and leaves only; one of the Albury sheets (NSW314593) comprises mixed material (this species and *E. goniocalyx*); the Gippsland material is atypical, and was collected from an area where this species and *E. angophoroides* are thought to intergrade (Brooker & Slee 1996).

The sheet chosen here as lectotype (NSW314589) has pressed but unmounted branchlets bearing adult leaves, immature fruits, two mature fruits in a packet and a few mature fruits attached to a twig. All material is in agreement with the protologue. It is consistent with a single gathering, and was collected before the publication of the name.

The identity of "Dr Andrews" is not known. This person does not seem to be any of the four "Andrews" listed in Hall (1978). Baker gave no clarification in the protologue, or in any other publication I have seen. Many New South Wales "Andrews" collections from around the turn of the century are referrable to Ernest Clayton Andrews, but he was never referred to as "Doctor" Andrews.

Eucalyptus conica H.Deane & Maiden, Proc. Linn. Soc. New South Wales 24: 612 (1900); *E. baueriana* var. *conica* (H.Deane & Maiden) Maiden, Proc. Linn. Soc. New South Wales 27: 216 (1902).

Type: New South Wales. 2 miles NE of Cowra, *R.H. Cambage s.n.*, 24 July 1899 (**lecto** NSW [NSW320940], here designated).

The protologue does not specifically mention any specimens, but it does say "on the Lachlan [River] it is called 'Apple Box' (R.H.C.)", and this may be considered a citation. "R.H.C." stands for Richard Hind Cambage, a noted botanical collector of the late 19th and early 20th centuries. The town of Cowra is situated on the Lachlan River. There are five Cambage specimens at NSW collected from near Cowra, apparently associated with three gatherings: two from "2 miles NE of Cowra" with different collection dates, and one from "6 miles SE of Cowra, 200 yards from the Lachlan River". All are consistent with the protologue, and all were collected before the publication of the name. The sheet NSW320940 is here selected as the lectotype. It has pressed but unmounted branchlets bearing adult leaves, mature buds and open flowers, and there is an attached packet containing a single fruit.

Hill (2002–04) suggested that *Eucalyptus baueriana* var. *conica* was described as a new taxon, and so he proposed a separate type specimen for the varietal name. However I have taken the view that Maiden (1902) intended "var. conica" as a new combination.

Eucalyptus decorticans (F.M.Bailey) Maiden, Crit. revis. Eucalyptus 5: 231 (1921); *E. siderophloia* f. *decorticans* F.M.Bailey, Queensland Agric. J. 26: 127 (1911).

Type citation: "Hab.: Eidsvold, Dr. T.L. Bancroft". **Type:** Queensland. Eidsvold, *T.L. Bancroft s.n., anno* 1911 (**lecto** BRI [AQ 099803], here designated (possibly holo)).

Bailey's description of the basionym in the Queensland Agricultural Journal is very brief, mentioning only the tree and the decortication of bark from the upper branches. He failed to describe the leaves, buds, flowers or fruits. It is nevertheless a valid description. Consideration was given by the present author to the possibility that Maiden's description of *E. decorticans* in *Crit. revis. Eucalyptus* 5: 231 could be thought of as a *sp. nov.*, rather than a new combination. However, a statement by Maiden therein quashes that possibility, *viz.* "I have therefore pleasure in bringing Mr. F. M. Bailey's forma *decorticans* (of *E. siderophloia*) up to specific rank …".

Chippendale (1988) cited the type of *E. decorticans* as "Eidsvold, Qld, *T.L.Bancroft s.n.*; holo: BRI; iso: FRI, K." However, the situation is not so straightforward.

The type folder for *E. decorticans* at BRI currently contains seven sheets of pressed and mounted material. All of that material is consistent with the taxon named by Bailey. That is, it matches other specimens collected of the ironbark species with smooth upper branches occurring in the Eidsvold area.

None of these seven sheets has an original label written by Bailey. Instead, all have a relatively recent type-written label stating "Eidsvold Burnett District. Queensland./ DR. T. L. Bancroft./ (Part of the type gathering of E. siderophloia F. V. Muell. var. decorticans F. M. Bailey)".

One sheet in particular casts serious doubt on the status of these specimens as original material. The said sheet has a determinavit slip with the word "Holotype" anonymously written on it. The sheet includes some branchlets bearing juvenile leaves, tied together with some cotton thread. Attached to this cluster of branchlets is a small label, also attached by cotton thread, which reads "Sucker leaves of E. decorticans", in the handwriting of T.L. Bancroft. Because the epithet *decorticans* was in existence when the label was written, it is clear that the material on this sheet is not original. By association, the other six sheets are almost certainly not original material. Furthermore, it seems highly unlikely that all seven sheets are from the same gathering, as they variously include immature buds, mature buds, immature fruits and mature fruits.

I have found only one sheet at BRI (AQ 099803) that has a label with Bailey's handwriting and has plant material conspecific with other collections of the gum-topped ironbark from the Eidsvold area. This sheet bears two pressed and mounted branchlets with adult leaves, and in a fragment packet there are two mature fruits. The label is old and has faintly stamped on it "Hab Eidsvold/ Dr Bancroft/ 1911". On this label, F.M. Bailey has written "Eucalyptus ?leucoxylon, FvM/ cannot be sure from the specimen. the only eucalypt specimen shoots bearing fruits in the packet/ FMB." The date "1911" stamped on the label is worrying, as this is the same year as the publication of the name. However, the fact that Bailey's *E. ?leucoxylon* identification is written actually *on* Bancroft's "1911" label supports the idea that the label and hence the specimen were available to Bailey before the publication of *E. siderophloia* f. *decorticans*. Unfortunately there is no surviving correspondence between Bailey and Bancroft that is relevant to this species.

This sheet is accepted as original material, and in view of the lack of other relevant specimens bearing Bailey's hand, it is here designated as lectotype.

Eucalyptus dunnii Maiden, Proc. Linn. Soc. New South Wales 30: 336 (1905).

Type: New South Wales. Acacia Creek, Macpherson Range, *W. Dunn 88*, 1 May 1905 (**holo** NSW (3 sheets) [NSW313318, NSW314312 & NSW313319]).

The protologue says "Acacia Creek, Macpherson Range, New South Wales side" and "(William Dunn, Forest Guard; specimen No. 88)". The name was published in September 1905 (Chapman 1991).

Maiden referred to a single specimen when he specified "W. Dunn 88", and it is clearly the holotype, but due to mistakes by later authors, some clarification is necessary here.

There are two specimens at NSW that were undoubtedly used by Maiden when drawing up his description:

1. a collection made on the 1st May 1905, comprising three sheets of pressed but unmounted material. Two sheets have branchlets bearing adult leaves, mature buds and flowers and an occasional fruit. The third sheet bears branchlets with juvenile leaves. Attached to one of the sheets of flowering specimens is a letter by Dunn prefaced 'No. 88'. The sheet bearing the juvenile leaves also has an original label by Dunn saying "No. 88/Eucalyptus "White Gum"/suckers/W.D.". These three sheets comprise the holotype. No duplicates of it are known.

2. a collection made on the 8th May 1905, comprising a single sheet. It bears mature fruits and immature buds, and there is no indication of a collector number.

Chippendale (1988) cited the type as "Acacia Ck, Macpherson Ra., NSW, 8 May 1905, W. Dunn 88 (holo: NSW; iso: BM, K)". In doing so, he has confused the two gatherings outlined above by associating the collection number "88" with the collection dated "8th May". Furthermore, the specimens at K and BM cited by Chippendale (*loc. cit.*) as isotypes are not original material. They were collected in October 1905, after the publication of the name.

Similarly, Hill (2002-04) cited a specimen at BRI as an isotype. The BRI specimen is also part of Dunn's October 1905 gathering and therefore not original material.

Eucalyptus fibrosa subsp. ***nubilis*** (Maiden & Blakely) L.A.S.Johnson, Contrib. New South Wales Nat. Herb. 3(3): 119 (1962), as *E. fibrosa* subsp. *nubila*; *E. siderophloia* var. *glauca* Maiden, Proc. Linn. Soc. New South Wales 24: 461 (1900); *E. nubilis* Maiden & Blakely, Crit. revis. Eucalyptus 8: 38 (1929).

Type: New South Wales. Dubbo-Coonamble road, *J.L. Boorman s.n.*, November 1897 (**lecto** NSW [NSW129812], *fide* Brooker et al. (1984: 522)).

The protologue says "Dubbo district (H. Deane, Nov., 1892; J.V. de Coque and J.L. Boorman, Nov., 1897)."

Brooker et al. (1984) have lectotypified the name thus: "Types: *E. fibrosa*, near the Brisbane River, Queensland, F. von Mueller; subsp. *nubila*, Dubbo-Coonamble Road, New South Wales, J.L. Boorman (NSW 129812)".

The lectotype is labelled *Eucalyptus siderophloia* var. *glauca* by Maiden, and it has written on the label "NSW 129812". This sheet gives the locality as "Dubbo-Coonamble road", it gives Boorman as collector with the date "Nov 1897". It comprises pressed but unmounted branchlets bearing juvenile leaves, adult leaves and mature fruits.

At first, it would seem that this specimen may not be one of those cited in the protologue, because the name of De Coque does not appear on the label. However, attached to the sheet is a portion of a letter (probably written by Boorman) that says (in part) "This is the plant that Mr D Coque wished Mr Maiden to make a special note of as he is of an opinion that it is quite distinct from any of the other three ironbarks of the district..."

Maiden, having read this, presumably felt that both Boorman (the specimen collector) and De Coque (who drew Boorman's attention to it) deserved to be mentioned.

Johnson (1962) changed Maiden & Blakely's epithet from *nubilis* to *nubila*, claiming that the original spelling was "clearly an unintentional error for *nubila*. Latin *nubilus* means 'dark or gloomy', reflected in Blakely's English name 'Dusky-leaved Ironbark', while *nubilis* means 'marriageable', inapplicable here". He further wrote, "Mr H.K. Airy Shaw, of Kew, has expressed the view (in litt.) that '*nubilis*' is an unintentional orthographic error which should be corrected." Maiden & Blakely did not comment on the etymology of their epithet, but because Blakely (1934) continued to use the same spelling, we can be sure *nubilis* was not an "unintentional error". Nor is it an orthographic error to be corrected (under Article 60), as *nubilis* is the correct feminine form of the Latin adjective *nubilis* meaning either "marriageable" or, according to Stearn (1992: 453), "ready for pollination".

The species epithet is not correctable under the Code, and the original spelling is restored here.

Eucalyptus laevopinea R.T.Baker, Proc. Linn. Soc. New South Wales 23: 414 (1898).

Type citation: "Nullo Mountain, Rylstone (J. Dawson); Never Never Mountain, Rylstone (R.T.B.), Gulf Road, Rylstone (R.T.B.)". **Type:** New South Wales. Nulla [Nullo] Mtn [near Rylstone], *J. Dawson s.n.*, 3 August 1898 (**lecto** BRI [AQ099608], here designated; isolecto: K [K000279885]).

The name was published on 9 December 1898 (Chapman 1991).

Maiden (1920: 329) wrote "Nullo Mountain, Rylstone, and Gulf road, Rylstone (R. T. Baker); the type". This cannot be considered a lectotypification, as Maiden has cited two of the three syntypes.

The lectotypification made by Brooker et al. (1984) with the words "Type: Nullo mountain, near Rylstone, NSW, R.T.Baker" is not priorable, because the citation in the protologue specified that the Nullo Mountain specimen was collected by J. Dawson.

All of the specimens at NSW from Nullo Mountain have been ascribed to R.T. Baker (hence not matching the cited specimens), although for one specimen (NSW329636), the collector name R.T. Baker has been crossed out and replaced (in L.A.S. Johnson's handwriting) by "(prob.) Dawson". No specimens matching the protologue and with the locality "Never Never Mtn" have been located. There is one specimen at NSW from Gulf Road, collected by Baker, but it is of poor quality.

Specimens dated 3/8/98 are present at BRI and K. The labels for these specimens are in R.T. Baker's handwriting and both say "Eucalyptus laevopinea R.T.B./ Myrtaceae/ Nulla Mt/ 3/8/98". The plant materials present on these two specimens match very well, confirming that they are from the same gathering. The sheet at K specifies the collector as "J. Dawson". The BRI specimen does not specify a collector, but as there are no other existing collections with this date, Dawson may be assumed. The BRI sheet is in full agreement with the protologue and is here selected as the lectotype. It has pressed and mounted branchlets bearing adult leaves and young buds, and there are mature fruits in a packet.

Eucalyptus longifolia Link, Enum. Hort. Berol. Alt. 2: 29 (1822).

Type citation: "Hab. in Australia". **Type:** New South Wales. Mt Hercules road, Razorback Range, 11 km SSW of Camden, *R.G. Coveny 7541, D.H. Benson & H. Bryant,* 17 March 1976 (**neo** NSW [NSW340964], here designated; isoneo BRI, CANB, K).

Link (1822) published the name *Eucalyptus longifolia* in an enumeration of plants growing at the Berlin Botanic Gardens. Although Link's description is almost 100 words long and includes measurements of leaves, petioles and peduncles, it is not diagnostic and it could apply to a number of species.

Lindley (1826) also adopted the name *Eucalyptus longifolia,* without making any reference to Link, and it is clear that he was unaware of Link's name. Lindley's publication apparently prompted Link to immediately publish an illustration of his *E. longifolia* (Link & Otto 1826). In the accompanying discussion Link & Otto stated that Lindley's *E. longifolia* was a different species, and that Link's name was published first. This illustration is sufficiently detailed to make the application of the name unambiguous.

Hill (2002–04) stated that a type specimen is present at B, "in herb. B. Auerswald", but the curator at Berlin Herbarium (R. Vogt, pers. comm. April 2008) has assured me that no *E. longifolia* material is present at B.

A flowering specimen at BM from "Herb. B. Auerswald" has been annotated by G.M. Chippendale as "probably an isotype" of *E. longifolia*, on the basis that the label "appears to be in Otto's writing". However, there are serious discrepancies between the protologue and this specimen:

The protologue states that the operculum is conical, but there is no mention of flowers. It also states the leaves to be "6 inches to a foot [15–30 cm] long" and "one inch and eight lines [4.2 cm] wide". In *E. longifolia*, leaves of this size typically occur on young plants less than three metres high at about the stage when they develop their first inflorescences.

The BM specimen bears flowers, but no opercula remain. It has leaves 7–13 cm long and 1.1–2.2 cm wide. In *E. longifolia*, these leaf dimensions are typical of specimens collected from mature trees, where fully developed adult leaves prevail.

The BM specimen differs sufficiently from the protologue to discount it as original material.

No original material could be found at other major European herbaria and so it is necessary to designate a neotype. The specimen selected here as neotype was collected near Sydney. The Sydney area is very likely to be the provenance of the seed collection from which plants were raised and described by Link.

Eucalyptus macarthurii H.Deane & Maiden, Proc. Linn. Soc. New South Wales 24: 448 (1899).

Type: New South Wales. Argyle, *W. Macarthur 142, anno* 1854 (**lecto** K [K000279769], *fide* Brooker et al. (1984: 466)).

The protologue states: "Sir William Macarthur collected its timber for the Paris Exhibition of 1855, it bearing the number 142 of the indigenous woods of the southern district...In the year 1864 Miss Atkinson (afterward Mrs. Calvert) collected it...Her original specimens are in the National Herbarium of Victoria,...Probably both Miss Atkinson and Dr. Woolls collected specimens,..." and "…confined to the counties of Camden and Argyle, N.S.W., as far as known at present."

Brooker et al. (1984) cited the type as follows: "Type: vicinity of Berrima, NSW, 1854, W. Macarthur (No 142)". In so doing they have lectotypified the name. The only known specimen corresponding to this citation is at K, and it is in accord with the protologue. Chippendale (1988: 357) and Slee et al. (2006) listed a syntype specimen for NSW from Macarthur's gathering, but neither Hill (2002–04) nor the present author could confirm its presence there.

It is doubtful whether Deane and Maiden ever saw *Macarthur 142*, or used it in drawing up their description of the species, but according to Article 9.2, Note 2, there is no requirement for a specimen to have been seen or used, it just has to be cited.

The label on the lectotype reads "Paris Exhib/ Sydney Woods/ Wooly gum of Argyle/ No 142/ Eucalyptus viminalis Lab/ 40–80 feet/ N.S. Wales/ W. Macarthur 1854".

Maiden (1916) explained that the name "Argyle" used by Macarthur refers to the County of Argyle, which is south-west of Sydney around the towns of Goulburn and Berrima. Brooker et al. (1984) apparently reinterpreted this as "vicinity of Berrima".

Eucalyptus microcorys F.Muell., Fragm. 2: 50 (1860).

Type: New South Wales. Hastings River, *H. Beckler s.n.,* undated [January-February 1860] (**lecto** MEL [MEL75551], here designated; isolecto K).

Mueller gave the following citation in the protologue: "In silvis ad flumina Hastings et McLeay River. Dr. Beckler. Ad flumen Brisbane. F.M.". There are two gatherings extant that can be associated with this citation. The first was collected near the Brisbane River by Mueller, and the other at the Hastings River by Beckler. The specimens of both gatherings are in agreement with the protologue. The Beckler gathering from Hastings River is of better quality, and the specimen at MEL is here designated as the lectotype. There is apparently no material collected by Beckler from the McLeay River now extant.

Eucalyptus ochrophloia F.Muell., Fragm. 11: 36 (1878).

Type: ?Paroo River, *?E. Palmer,* undated (**lecto** MEL [MEL703966], here designated).

No specimens were cited by Mueller in the protologue, but he did mention two locations: "Ad ripas et in planitiebus secus fluvios Warrego et Paroo". Only two specimens have been located that can be considered original material of this name. The first is a specimen at K with a label bearing the words "Warrego River" in Mueller's handwriting. Chippendale (1988) listed F. Mueller as the collector of this specimen. That cannot be correct, as Mueller never visited south-western Queensland, but the collector of the specimen remains obscure.

The second is a specimen housed at MEL [MEL703966], bearing the label "Euc ochrophloia FvM 'Yellowjacket' " in Mueller's handwriting. This sheet has no information on the collector, collection date or locality, but mounted on it is a square of paper with a Latin description by Mueller comparing this species with *E. gracilis*. It repeats almost word for word a part of the description given in the protologue. The presence of this Latin description strongly suggests that Mueller used this specimen when compiling his manuscript of *E. ochrophloia*. The specimen mounted on MEL703966 is entirely consistent with the protologue and it is here designated as the lectotype of *E. ochrophloia*.

Another significant specimen of *E. ochrophloia* annotated by Mueller is to be found at MEL [MEL704020]. It is not original material as it was collected in 1884, after the publication of the name. The label for the specimen is written in the handwriting of F.M. Bailey, and states "specimen collected by E. Palmer Esq. M.L.A. on the Bulloo & Paroo". Mounted beside the specimen is a letter from Bailey to Mueller which says in part "our mutual friend Mr E. Palmer has just given me a few very nice fresh specimens of the gum you will remember I sent to you some years ago, the Paroo Yellow Jacket, and you named it *Eucalyptus ochrophloia*...". This letter provides strong evidence that Bailey sent at least one of the specimens mentioned above, and gives the only clue that MEL703966 *may* have been collected by Palmer from the Paroo River. It seems that Bailey on both occasions passed the entirety of the *E. ochrophloia* material to Mueller, as there are no specimens at BRI that bear Bailey's or Palmer's name, or any early collections without date and collector that could correspond to a Palmer collection.

Eucalyptus oreades R.T.Baker, Proc. Linn. Soc. New South Wales 24: 596 (1900); *E. virgata* var. *altior* H.Deane & Maiden, Proc. Linn. Soc. New South Wales 26: 124 (1901); *E. altior* (H.Deane & Maiden) Maiden, Crit. Revis. Eucalyptus 6: 272 (1922), *nom. illeg.*

Type: "near Lawson, Apr 1899, Baker & Smith", *fide* Brooker et al. (1984: 314); **lecto:** New South Wales. Adelina Falls, Lawson, *R.T. Baker & H.G. Smith s.n.*, 22 April 1899 (NSW [NSW325376], here designated; isolecto: K [K000279928], NSW [NSW325377, NSW325378 & NSW325379]).

The protologue says "Hab. - Lawson (H.G. Smith and R.T.B.); Mount Victoria and road to Jenolan Caves (R.H. Cambage.)"

Brooker et al. (1984) achieved a first-step lectotypification with the statement "Type: near Lawson, Apr 1899, Baker & Smith". There is only one known gathering that matches this citation, but there are specimens of it at both K and NSW. NSW 325376 is here designated as the (second-step) lectotype.

G.M. Chippendale annotated four sheets at K as isosyntypes, but only one sheet is indisputably a type. The other sheets have no label indicating their origin or date of collection.

Eucalyptus planchoniana F.Muell., Fragm. 11: 43 (1878).

Type: Queensland. Eight Mile Plains, *F.M. Bailey s.n.*, undated (**lecto** MEL (2 sheets) [MEL705638 & MEL703450], here designated; isolecto BRI [AQ024086, sheet 2 & sheet 3]).

Mueller described *E. planchoniana* using material collected by F.M. Bailey. The protologue includes the statement "In collibus aridis subarenosis prope sinum orarium

Moreton-Bay; F. Bailey". Other salient parts of the protologue read "Flores evolutos nondum accepi" and "antherae tantum in junioribus alabastris observatae". These both indicate that Mueller saw only young (immature) buds.

There are three specimens at MEL annotated as "Euc. planchoniana" by Mueller.

The first sheet, MEL1611102, has three leafy branchlets mounted on it, two with mature buds and open flowers, and a third bearing a single fruit. This sheet has a label written by Mueller saying "Moreton Bay, February 1879, F.M. Bailey".

The second sheet, MEL705638, has a single leafy branchlet mounted on it, bearing immature buds and no fruits. The label says "Eucalyptus near eximia Schau/ Hab on poor sandy dry ridges Eight Miles Plains/ FMB" in the handwriting of F.M. Bailey, and then "Euc planchoniana FvM" in the handwriting of Mueller.

The third sheet, MEL 703450, has no mounted material, but there are some mature fruits in a fragment packet, some of which have been dissected. Its label says "Eight Miles Plain" in Mueller's handwriting.

Chippendale (1988) cited the type as "8 Mile Plains, Moreton Bay, 1879, *F.M. Bailey s.n.*; holo: MEL; iso: BRI, NSW". Chippendale annotated MEL1611102 as "holotype or isotype". However, that sheet is not original material as the date on the label (February 1879) is later than the publication of the name. Furthermore, Mueller stated in the protologue that he saw only immature buds, whereas this specimen bears mature buds and open flowers.

MEL705638 is considered to be original material because the label is in the handwriting of F.M. Bailey, and the habitat information given by Bailey on the label ("on poor sandy dry ridges") is almost literally translated by Mueller in the protologue ("In collibus aridis subarenosis"). The presence of only immature buds is in agreement with the protologue. MEL703450 is also considered to be original material, and part of the same gathering as MEL705638, because Mueller described fruits and seeds, and those are absent from the latter. These two sheets are therefore chosen as lectotype.

At BRI there is material mounted on three sheets that has been annotated as "isotype". One sheet has mounted on it some flowering branchlets, and some fruits in a packet. This is not original material, for the reasons outlined above. The other two sheets bear branchlets with immature buds, consistent in size and appearance to the lectotype. One of these sheets has a label in Bailey's handwriting saying "A stringybark eucalypt from 8m Plains FMB/ E sp new near E. eximia, Schau". These two BRI sheets are considered to be part of the same gathering as the lectotype, and hence they are designated as isolectotype.

The label of the lectotype gives the locality as 'Eight Mile Plains'. This name is still in current use for a suburb of Brisbane, south of the city centre. Bailey almost certainly obtained his specimens from the nearby Toohey Forest - Griffith University area, where *E. planchoniana* is still quite common today.

Eucalyptus propinqua H.Deane & Maiden, Proc. Linn. Soc. New South Wales 10 (2nd series): 541 (1896).

Type: New South Wales. Stroud Rd, *A. Rudder s.n.*, 10 February 1893 (**lecto** NSW [NSW 308067], *fide* Chippendale (1988: 203).

No specimens were cited in the protologue, the only information being "Range. - From the Hawkesbury River northwards at least as far as the Tweed River."

Maiden (1917) stated: "Type. Dungog-Stroud Road, N.S.W. (A. Rudder)".

There is a specimen at NSW whose label reads "Stroud Rd, 10 Feb 1893, A. Rudder". It comprises pressed but unmounted branchlets bearing adult leaves, mature buds and open flowers. There is also a relevant specimen at BRI. Its label has the printed heading "National Herbarium of New South Wales", and written below, in Maiden's handwriting, is "Stroud, 1895, A. Rudder". Both specimens are in accord with the protologue. The citation by Maiden (1917) does not constitute a lectotypification, since it encompasses two different gatherings.

The 1893 specimen at NSW was effectively selected as lectotype by Chippendale (1988) with the statement "T: Dungog-Stroud Road, N.S.W., 10 Feb. 1893, *A. Rudder s.n.*; holo: NSW". Under Article 9.8, the use of the term "holotype" by Chippendale is correctable to "lectotype".

Eucalyptus quadrangulata H.Deane & Maiden, Proc. Linn. Soc. New South Wales 24: 451 (1899).

Type: "Hill Top, Box Knob. The type (J.H.M.)", *fide* Maiden (1915: 77); **lecto:** New South Wales. Hill Top, Box Knob, *J.H. Maiden s.n.*, January 1896 (**lecto** NSW [NSW317818], here designated; **isolecto** NSW [NSW317817, NSW317819 & NSW317820].

The protologue says "found only in the neighbourhood of Hill Top, about 70 miles south of Sydney". According to Article 37.3, Note 2, the naming of a locality in the protologue without any reference to a collector does not constitute a specimen citation. Hence Hill (2002-04) was correct in saying "No type was cited".

Maiden (1915) stated "Hill Top, Box Knob. The type (J.H.M.)" There is only one known gathering from this location that was collected by J.H. Maiden alone, and the specimens at NSW are the only ones known. Therefore this constitutes the first-step in lectotypification. The lectotype chosen here from this gathering comprises pressed but unmounted branchlets bearing adult leaves, almost-mature buds and mature fruits.

The lectotypification by Brooker et al. (1984), i.e. "Type: Hilltop, New South Wales, Sept. 1899, J.H. Maiden and J.L. Boorman" is not valid, as Maiden had previously chosen a different gathering as the type.

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Naming *Stylidium* (Stylidiaceae): an historical account, with specific reference to *S. graminifolium* and *S. lineare*

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Abstract

An overview of the debate surrounding the correct generic name for the triggerplants (*Stylidium* Sw., *Candollea* Labill., *Ventenatia* Sm.; Stylidiaceae) is provided. The authorship of *Stylidium* and the four species published in Willdenow's *Species Plantarum* in 1805 is here attributed to Swartz in Willdenow rather than Swartz ex Willdenow, since Willdenow clearly credits these taxa to Swartz; however, the month of publication of these taxa could not be verified. The nomenclatural implications of a publication date subsequent to that of *Candollea*, also published in 1805, are discussed. *Stylidium graminifolium* Sw., previously thought to be based on a gathering by Banks and Solander, is shown to be based on a collection by Dr John White, first Surgeon-General of New South Wales. The type of *S. lineare* Sw. was similarly collected by White. A revised type citation and synonymy are provided for both species and lectotypes selected for *Stylidium graminifolium* var. *angustifolium* Mildbr., *Ventenatia major* Sm. and *V. minor* Sm.

Introduction

The first known herbarium collections of the triggerplant genus *Stylidium* Sw. (Stylidiaceae) are those made by Sir Joseph Banks and Daniel Solander in 1770 during their momentous voyage of discovery under Captain Cook. They made collections of seven species, one from Botany Bay and the remainder at the Endeavour River, with Solander later giving these collections the manuscript name *Lobeliastrum* (Diment et al. 1984). However, Solander and Banks never published the results of their voyage and it was 40 years before Robert Brown (1810) provided their collections with formal names.

Although additional triggerplant collections were made during the 18th century from Australia (Jacques-Julien Houtton de Labillardière, John White, David Nelson) and south-east Asia (John Koenig), the genus was not formally named until the early nineteenth century, at which time three generic names were applied: *Candollea* Labill. (Labillardière 1805), *Stylidium* Sw. (in Willdenow 1805) and *Ventenatia* Sm. (Smith 1806). An overview of the ensuing debate surrounding the correct generic name for the triggerplants is provided by both Raulings and Ladiges (2001) and Jackson and Wiltshire (2001); however, these accounts differ in several respects.

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Furthermore, new information has come to light following examination of botanical literature and herbarium specimens housed at various institutions in Europe, necessitating this review. Special attention is paid to the type collections of both *S. graminifolium* Sw., a species widespread in south-eastern Australia, and the New South Wales endemic *S. lineare* Sw.

Generic Name

Swedish Professor Peter Olof Swartz described four species of *Stylidium* in a manuscript he sent Carl Ludwig Willdenow, then Director of the Berlin Botanical Garden, in the Spring of 1803 (Willdenow 1807: 53). This manuscript was destined for publication in Volume 5 of *Neue Schriften Gesellschaft Naturforschender Freunde zu Berlin*; however, it was not published until 1807 when it appeared in Volume 1 of *Magazin Gesellschaft Naturforschender Freunde zu Berlin*, a new series of the same journal. In the intervening period, the genus was published by Willdenow in *Species Plantarum* (1805) in which he credits the genus and the four species in question to Swartz.

In the same year, Labillardière described six species of triggerplant under the name *Candollea* (Labillardière 1805). These findings were announced at the French Institute on July 8th 1805 and subsequently printed in *Annals du Muséum d'Histoire Naturelle, Paris*. Upon becoming aware of Swartz's work, Labillardière immediately accepted the name *Stylidium* in *Novae Hollandiae Specimen Plantarum* (Labillardière 1806a) and reapplied the name *Candollea* to a genus in Dilleniaceae. In both cases, his use of the name *Candollea* was illegitimate since Brisseau-Mirbel (1803) had earlier applied the name to a genus in the Polypodiaceae.

James Edward Smith unwittingly provided a third name for the triggerplants, describing two species in his *Exotic Botany* under *Ventenatia* (Smith 1806). *Ventenatia* was treated as a synonym of *Stylidium* by Willdenow (1807) who drew attention to its previous use by both Cavanilles (1797, Epacridaceae) and Palisot de Beauvois (1805, Flacourtiaceae); the name had also been applied by Trattinnick (1802, Euphorbiaceae). Upon accepting the name *Stylidium*, Smith (1807) observes that this generic name had previously been used by Loureiro (1790, Alangiaceae), later commenting that "there is great probability of his [Loureiro's] genus not being a good one and we hope our *Stylidium* will remain undisturbed" (Smith 1819).

Throughout the 19th century, the name *Stylidium* was retained for the triggerplants by the majority of botanists (e.g. Willdenow 1807, Salisbury 1808, Brown 1810, Endlicher et al. 1838, de Candolle 1839, Lindley 1839, Sonder 1845, Bentham 1868, Bentham & Hooker 1876); however, Ferdinand von Mueller was adamant that the correct name for the genus was *Candollea* and he therefore made the required new combinations for species previously published under *Stylidium* (Mueller 1882). Despite Mueller's conviction, only Schönland (1894), de Wildman (1900), Britten (1905) and Maiden and Betche (1916) followed Mueller's lead, and the name *Stylidium* remained in common usage (e.g. Fitzgerald 1902, Moore 1902, Diels & Pritzel 1905, Mildbraed 1908, Fitzgerald 1918, Moore 1920, Ostenfeld 1921, Domin 1923, Domin 1930, Schwarz 1927). On this basis, Thomas Sprague of the Royal Botanic Gardens, Kew submitted a proposal to the 1930 International Botanical Congress in Cambridge to conserve the name *Stylidium* Sw. against *Stylidium* Lour. (Sprague 1929). He further argued his case on the grounds that *Stylidium* Sw. is the type of the family name Stylidiaceae, and that it would be confusing to use the name *Candollea* since it had been applied by

Labillardière to another Australian genus. The formal conservation of *Stylidium* does not, however, appear in the list of accepted proposals in the Cambridge Code. Whilst Sprague's recommendation was approved by the appropriate Group Committee, it was still subject to approval by the General Committee and therefore by the next Congress in Amsterdam in 1935 (Briquet 1935). Although approved in Amsterdam (Sprague 1940), no official Code was produced from this congress due to the threat of war and as a result the formal conservation of *Stylidium* first appears in print in the Stockholm Code (Lanjouw 1952).

On the authorship and publication date of *Stylidium*

Four species of *Stylidium* were published in Willdenow's *Species Plantarum*: two from south-east Asia (*S. tenellum* Sw. and *S. uliginosum* Sw.) and two from Australia (*S. lineare* Sw. and *S. graminifolium* Sw.). Willdenow clearly attributes these taxa to Swartz, citing Swartz's unpublished manuscript subsequent to the genus name as well as after the species diagnoses, which are identical to those in Swartz's (1807) manuscript. I argue that in accordance with IBCN Art. 46.2, and in agreement with Sprague (1929) and Lanjouw (1952), the authorship of these four species and of the genus should be attributed to Swartz in Willdenow (i.e. *Stylidium* Sw.) and not Swartz ex Willdenow, as has commonly been the case. Accordingly, the type specimens for these taxa are those viewed by Swartz and not by Willdenow.

Raulings and Ladiges (2001: 903) state that *Stylidium* was published in December 1805 (i.e. after *Candollea*), whereas Bailey (1917: 3278) and Jackson and Wiltshire (2001: 939) suggest that it was named a few months earlier than *Candollea*. I have been unable to verify the publication date: a month is not provided on the frontispiece of the relevant volume of *Species Plantarum* nor is it given by Stafleu & Cowan (1988: 303). Similarly, I have not been able to confirm the month of publication of *Candollea*, even though Labillardière is known to have verbally presented his paper on the genus on the July 8th 1805. Whilst Salisbury (1808) states that "…a full extract from this, with figures and dissections, was immediately printed in the Annales du Museum", there is no indication on the frontispiece of the relevant volume of this journal of the date it was printed.

It is of note that Willdenow (1807), in an article that follows Swartz's 1807 publication, accepts the name *Stylidium* commenting that in such situations it is preferable to retain the first designation. Similarly, Labillardière (1806b: 400) states "Le genre que j'ai publié dans le Annales du Museum d'histoire naturelle, à la page 451 du VI.^{e} volume, sous le nom de *Candollea*, avoit été désigné peu de temps auparavant sous celui de *Stylidium*, par M. Swartz" [The genus that I published under the name of *Candollea* in *Annals du Museum d'Histoire Naturelle*, on p. 451 of volume 6, was designated a little time beforehand by Swartz under the name of *Stylidium*]. However, it is unclear whether Willdenow and Labillardière are referring to the publication of *Stylidium* in Willdenow's *Species Plantarum* or its description in Swartz's completed, but as yet unpublished manuscript. The possibility therefore remains that *Stylidium* was published subsequent to *Candollea*. This would have no nomenclatural repercussions at the generic level since *Stylidium* has been conserved; however, there would be implications at the species level (i.e. for the species named by both Labillardière and Swartz), as discussed in the notes under *S. graminifolium* and *S. lineare* below.

The type collections of *S. graminifolium* and *S. lineare*

According to two recent taxonomic treatments of the *S. graminifolium* complex, Swartz provided no information about the specimen he used to describe *S. graminifolium* (Jackson & Wiltshire 2001, Raulings & Ladiges 2001). Both studies conclude that Swartz, who worked in London at the Banksian Herbarium during 1786 and 1787, based his description on the collection of this taxon by Banks and Solander from Botany Bay. A specimen from this voyage, housed at the Natural History Museum, London and comparable to the drawing published in Banks' Florilegium, was chosen as a suitable lectotype.

During his time in London, Swartz wrote most of his *Prodromus*, a work on West Indian botany which was the forerunner to the larger *Flora Indiae Occidentalis* (Stearn 1980, Nicolson & Jarvis 1990). I have found no evidence to suggest that he looked at material of *S. graminifolium* at this time, nor to support the suggestion by Jackson and Wiltshire (2001: 939) that a duplicate specimen of *S. graminifolium* was taken by Swartz with Banks' permission to publish a description. Moreover, the decision to lectotypify a specimen collected by Banks and Solander is in conflict with information provided by Swartz (1807).

After his description of *S. lineare*, but in reference to both *S. lineare* and *S. graminifolium*, Swartz (1807: 51) states: "Diese beyde Arten sind aus Neu Holland, und wie ich vermuthe, wachsen sie in der Nähe von Port Jackson. Ich habe sie der Güte meines verehrungswürdigen Freundes, des Herrn Doctor Smith in England, zu verdanken. Er hat mir beyde unter dem Namen Species No. 1 und 2 novi generis Orchidearum mitgetheilt" [Both of these species are from Australia and I presume grow in the vicinity of Port Jackson. I am indebted to the generosity of my admirable friend in England, Dr Smith. He has given both specimens to me and communicated them under the names Species 1 and 2, a new genus of Orchidaceae].

The two specimens in question were collected by Dr John White, the first Surgeon-General of New South Wales. White, who arrived with the First Fleet in 1788, collected flora in the vicinity of Sydney and sent his specimens to Smith (Orchard 1999). Smith, initially thinking that these collections corresponded to a new genus of Orchid, sent duplicates to Swartz, who had a special interest in Orchidaceae. Unaware of the description of *Stylidium* that appeared in Willdenow's *Species Plantarum*, Smith (1806) used White's collections to describe *Ventenatia major* Sm. (*S. graminifolium*) and *V. minor* Sm. (*S. lineare*). Curiously, Smith later lays claim to having first applied the name *Stylidium* to the triggerplants: "*Stylidium*, was first so called by the writer of the present article, who sent specimens under that name to Labillardière and Swartz, and the latter published an account of the genus…" (Smith 1819).

The specimens sent to Swartz by Smith are located in Swartz's herbarium at the Swedish Museum of Natural History (S). Two sets of handwriting are evident on each specimen label: Smith's and Johan Wikström's, Swartz's successor. On the label for *S. lineare* (Fig. 1), Smith writes "novum genus Orchidearum No. 2". Wikström subsequently writes "J.E. Smith scripsit et misit" [J.E. Smith has written it and sent it] and replaces Smith's family placement with the genus name *Stylidium*. Wikström also annotates the sheet with Swartz's genus name and indicates that the specimen is part of Swartz's herbarium. On the label for *S. graminifolium* (Fig. 2), Smith writes "alia species generis No. 2" [another species of genus No. 2]. Wikström similarly annotates the label as having been written by Smith, and notes Swartz's species name on both the label and the sheet.

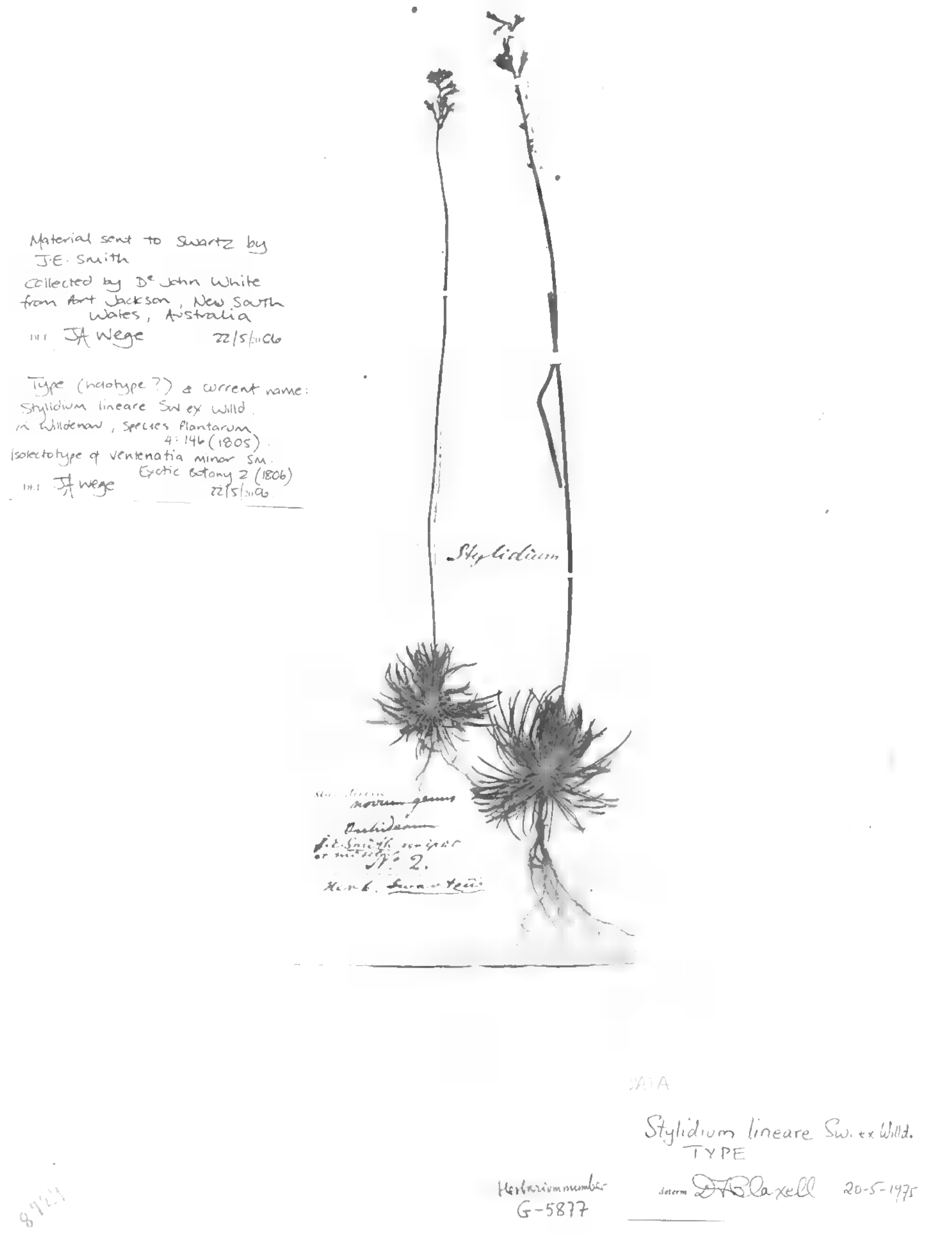

Fig. 1. Holotype of *Stylidium lineare* Sw. (S), collected by Dr John White and sent to Swartz by J.E. Smith.

The specimen of *S. lineare* (Fig. 1) comprises two individuals; the specimen on the right, which has had some flowers removed, is comparable to Swartz's illustration (Swartz 1807: Tab. 1, Fig. 2). The specimen of *S. graminifolium* (Fig. 2) is fragmentary, comprising two scape portions and lacking leaf material. The scape on the left hand side, which has similarly had some flowers removed, is a reasonably good match for the illustration provided by Swartz (1807: Tab. 1, Fig. 1). The whereabouts of the leaf rosette, also illustrated by Swartz, is unknown.

There are duplicates of White's two *Stylidium* collections in Thunberg's herbarium at Uppsala University; an individual of each species has been mounted together on the same sheet (UPS-THUNB 21556). There is an annotation on the reverse of the sheet in Swartz's hand that reads "ex Novae Hollandiae per Smith"; however, it is not clear whether this material was used by Swartz to compile his description. In view of the good comparison between Swartz's drawings and the material housed at S, the specimens at S are treated below as holotypes.

Stylidium graminifolium Sw., in Willd., Sp. Pl. 4(1): 146 (1805).
Candollea graminifolia (Sw.) F.Muell., *Syst. Cens. Aust. Pl.*: 85 (1882).

Type citation: "Swartz Nov. Act. Soc. Natur. Scrut. Berol. 5. p … [Ges. Naturf. Fruende Berlin Mag. Neuesten Entdeck. Gesammten Naturk. 1: 49] f. 2 [f. 1]."

Type specimen: Port Jackson, New South Wales, *J. White s.n., s. dat.* (holo: S 06-3470!; iso: LINN, Smith Hb. 1416.1!, LINN, Smith Hb. 1416.2! 2nd scape from right, LIV!, UPS-THUNB 21556! right hand specimen).

Ventenatia major Sm., *Exot. Bot.* 2: 13, t. 66 (1806); *Stylidium majus* (Sm.) Druce, *Bot. Soc. Exch. Club Brit. Isles* 4: 649 (1917), nom illeg., nom. superfl. **Type:** Port Jackson, New South Wales, *J. White s.n., s. dat.* (lecto, here designated: LINN, Smith Hb. 1416.1!; isolecto: LINN, Smith Hb. 1416.2! 2nd scape from right, LIV!, S 06-3470!, UPS-THUNB 21556! right hand specimen).

Stylidium canaliculatum Poir., in Lamarck, Encyclopédie Méthodique, Botanique Suppl. 5: 412 (1817), *nom illeg., nom. superfl.* **Type citation:** Nouvelle-Hollande (Smith, *l.c.*).

Type specimen: Port Jackson, New South Wales, *J. White s.n., s. dat.* (holo: P, *n.v.*; iso: LINN, Smith Hb. 1416.1!, LINN, Smith Hb. 1416.2! scape portion 2nd from right, LIV!, S 06-3470!, UPS-THUNB 21556! right hand specimen).

Stylidium graminifolium var. Hook., *Fl. Tasman.* 1: 235 (1856).

Stylidium graminifolium var. *angustifolium* Mildbr., in Engler, Pflanzenr. Heft 35, IV. 278: 73 (1908). **Type citation:** Victoria: bei Melbourne (F. v. Mueller!); Dandenong (F. v. Mueller!); oberer Yarra River (F. v. Mueller!). **Type specimen:** near Melbourne, *F. Mueller s.n., s. dat.* (lecto, here designated: W!).

Stylidium graminifolium var. *album* F.M.Bailey, The Queensland Flora 3: 887 (1900). **Type:** Cleveland, *W.R. Kefford s.n., s. dat.* (holo: BRI, *n.v.*).

Notes: a neotype was chosen by Raulings and Ladiges (2001: 925) for *Stylidium graminifolium* var. *angustifolium* since the original material used by Mildbraed (1908) in Berlin was destroyed in WWII. A syntype that conforms to Mildbraed's description of this taxon has since been located at the Natural History Museum in Vienna (W) and is chosen here as a suitable lectotype. Raulings and Ladiges (2001: 925) lectotypified Smith's illustration of *V. major* after failing to find a suitable specimen during a visit

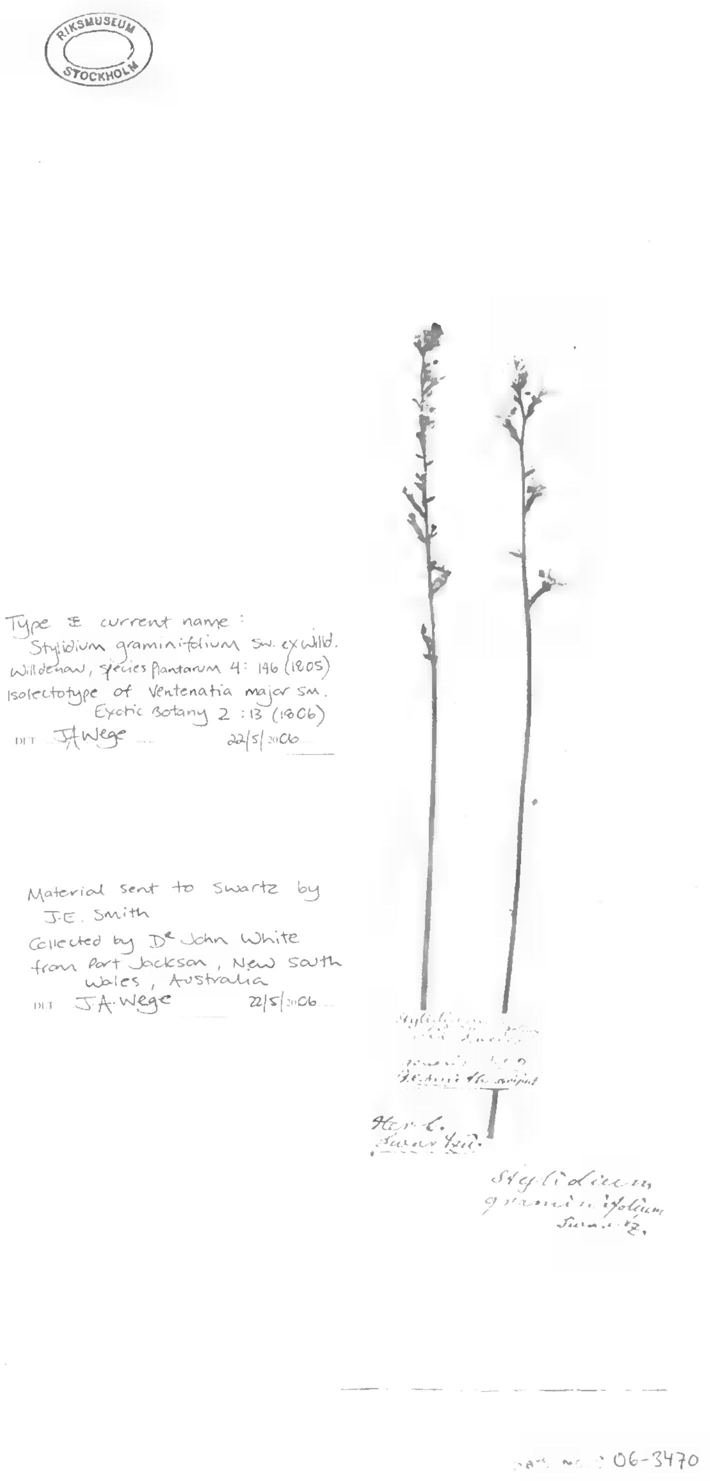

Fig. 2. Holotype of *Stylidium graminifolium* Sw. (S), collected by Dr John White and sent to Swartz by J.E. Smith.

to the Linnaean Society of London. I have located relevant specimens in the Smith Herbaria at the Linnaean Society and the National Museums Liverpool. It is likely that at the time of Raulings' visit to London, the specimen at the Linnaean Society was on loan to the National Museums Liverpool, being cleaned and databased at the as part of the Smith Herbarium Conservation Project. In accordance with IBCN Art. 9.10, *V. major* is relectotypified herein; the designated specimen conforms to Smith's original description of the species.

Jackson and Wiltshire (2001: 942, 953) consider *Candollea serrulata* Labill. and *C. umbellata* Labill. to be synonymous with *S. graminifolium* whereas Raulings and Ladiges (2001: 928) place both taxa into synonymy under the recently reinstated *S. armeria* (Labill.) Labill. If the former interpretation is accepted, and the publication date of *Candollea* is found to precede that of *Stylidium*, then the name *S. graminifolium* would need to be conserved against both *C. serrulata* and *C. umbellata*. Despite having examined types for all of Labilladiere's names, I am unable to confidently resolve this discrepancy at this point in time. An accurate interpretation of these types is dependent on a detailed knowledge of the full range of variation exhibited by *S. graminifolium* and allied taxa and I have little material at hand and a very limited field knowledge. A full taxonomic revision of this complex appears necessary in view of the different taxonomic outcomes presented in the two aforementioned studies.

Stylidium lineare Sw., in Willd. *Sp. Pl.* 4(1): 146 (1805). *Candollea linearis* (Sw.) F.Muell., *Syst. Cens. Aust. Pl.:* 85 (1882).

Type citation: "Swartz Nov. Act. Soc. Natur. Scrut. Berol. 5. p … [Ges. Naturf. Fruende Berlin Mag. Neuesten Entdeck. Gesammten Naturk. 1: 50] f. 2."

Type specimen: Port Jackson, New South Wales, *s. dat.*, *J. White s.n.* (holo: S G-5877!; iso: LINN, Smith Hb. 1416.2! excluding 2nd scape from right, LIV!, MANCH! MEL 2235241!, UPS-THUNB 21556! left hand specimen)

Candollea setacea Labill., *Ann. Mus. Hist. Nat.* 6: 455 (1805); *Stylidium setaceum* (Labill.) Labill., *Nov. Holl. Spec. Plant.* 2: 65 (1806). **Type citation:** "terra van-Leuwin." **Type specimen:** [likely to have been gathered at Port Jackson, New South Wales, collector unknown, probably *Leschenault* or *J. White*] (holo: FI 113185).

Ventenatia minor Sm., *Exotic Bot.* 2: 15, t. 67 (1806). **Type:** Port Jackson, New South Wales, *J. White s.n.*, *s. dat.* (lecto, here designated: LINN, Smith Hb. 1416.2! excluding 2nd scape from right; iso: LIV!, MANCH!, MEL 2235241!, S G-5877!, UPS-THUNB 21556! left hand specimen).

Stylidium planifolium Poir., in Lamarck, Encyclopédie Méthodique, Botanique Suppl. 5: 412 (1817), nom illeg., nom. superfl. **Type citation:** "Nouvelle - Hollande (Smith, *l.c.*)." **Type specimen:** Port Jackson, New South Wales, *J. White s.n.*, *s. dat.* (holo: P, *n.v.*; iso: LINN, Smith Hb. 1416.2! excluding 2nd scape from right, LIV!, MANCH! S G-5877!, UPS-THUNB 21556! left hand specimen).

Stylidium aciculare Sond., in Lehmann, J.G.C. *Pl. Preiss.* 1(3): 373, adnote (1845). **Type:** Nov. Hollandia, *J.S.C.D. D'Urville*, *s. dat.* (holo: B, Herb. Kunth, *n.v.*, destroyed in WWII).

Notes: LINN Smith Hb. 1416.2 comprises four individuals and two scape portions of *S. lineare* (collectively the lectotype of *V. minor*, as designated above) as well as a single scape portion of *S. graminifolium* (second from the right). The two species are superficially similar and therefore this intermixing is not surprising. Differences in scape indumentum between the two species are useful when identifying inflorescence fragments: unlike *S. graminifolium*, in which the scapes have glandular hairs along their entire length, *S. lineare* has scapes in which the glandular hairs are restricted to the upper portion.

To date, there has been confusion as to the correct identity of *S. setaceum* (Labill.) Labill. (*Candollea setacea* Labill.), recorded from "terra van-Leuwin" by Labillardière (1805, 1806a) and published, rather unusually, without an illustration. Labillardière (1806a) considered *S. setaceum* a separate taxon to *S. lineare* in view of its apparent lack of appendages in the throat of the flower; however, I have examined the holotype of *S. setaceum* and am confident that it is conspecific with *S. lineare*. The presence of throat appendages — which can be readily overlooked or misinterpreted on pressed *Stylidium* specimens — could not be confirmed since this would have caused unacceptable damage to the specimen; however, features of leaf morphology, indumentum distribution, and inflorescence structure were without doubt comparable to *S. lineare*. If the publication date of *S. lineare* is found to be later than *C. setacea* then the name *S. lineare* would need to be conserved against *C. setacea* in order for it to be retained. If a precise publication date cannot be determined, then it may be prudent to formally reject the name *C. setacea*.

Labillardière miscommunicated the type locality of *S. setaceum*, an error he repeated for several other Australian taxa (Nelson 1974, 1975). Specimens with the label "terra van-Leuwin" were supposedly collected in the vicinity of Esperance in Western Australia, Labillardière's only known landfall in this State (Nelson 1975); however, *S. lineare* is endemic to the east coast of Australia. As a consequence, *S. setaceum* was tentatively regarded by Bentham (1868) and Nelson (1974, 1975) as conspecific with *S. spinulosum* R.Br., a species endemic to the south coast of Western Australia which has a very similar leaf morphology to *S. lineare*; however, both authors noted the possibility of *S. setaceum* being synonymous with *S. lineare*. Although Mildbraed (1908: 72) treated *S. setaceum* as a synonym of *S. lineare*, he did so with a degree of doubt. Both *S. lineare* and *S. spinulosum* are restricted to regions of Australia that were not visited by Labillardière. Nelson (1974, 1975) tentatively suggested that Leschenault de la Tour collected the type of *S. setaceum* from King George Sound in Western Australia, in which case the name *S. setaceum* would have nomenclatural priority over *S. spinulosum* (published by Robert Brown in 1810). Phenology records do not support this suggestion: the holotype of *S. setaceum* is in very early flower and yet *S. spinulosum* does not flower in February, the time of Leschenault's visit to Albany.

The type of *S. setaceum* is likely to have been collected from Port Jackson in New South Wales, but it is unclear who made this gathering. It may have been acquired by Leschenault who visited Port Jackson and is known to have given material to Labillardière (Nelson 1974, 1975); however, it is equally plausible that the type was collected by John White, first Surgeon-General of New South Wales. Smith (1819) states that he sent duplicates of White's *Stylidium* collections to Labillardière.

There has been similar confusion as to the true identity of *S. aciculare*, which Sonder (1845) based on a collection in Kunth's herbarium made by d'Urville. Bentham (1868: 11), who did not view the type, placed *S. aciculare* into synonymy under *S. spinulosum*; however, Mildbraed (1908: 72), who did view d'Urville's collection, treated it as a distinct taxon with close affinity to *S. lineare*. The name has never been applied in

Australia. It is not known whether d'Urville made the collection on the east or west coast; he twice visited Australia and made collections from both New South Wales and King George Sound (Orchard 1999). Furthermore, the holotype was destroyed in World War II (Botanical Museum Berlin-Dahlem 1999) and no duplicates are known, making the application of this name difficult. Sonder (1845) describes the scape of *S. aciculare* as glabrous and the inflorescence glandular, and therefore I tentatively regard it as a synonym of *S. lineare* rather than *S. spinulosum*.

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A new subfamilial and tribal classification of Restionaceae (Poales)

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Abstract

Restionoideae Link, with the newly described Sporadanthoideae and Leptocarpoideae, represent major clades of Restionaceae distinguished by analyses of chloroplast DNA data. These subfamilies are supported by features of morphology, culm anatomy, pollen and phytochemistry. Sporadanthoideae occur in Australia and New Zealand, Leptocarpoideae principally in Australia but with representatives also in New Zealand, New Guinea, Aru Islands, Malesia, Hainan Island and Chile, while Restionoideae are in sub-Saharan Africa and Madagascar. Two tribes, Restioneae Bartl. and Willdenowieae Mast. are recognised within Restionoideae, but their circumscriptions are very different from those of the tribes previously recognised within African Restionaceae. The relationship of Centrolepidaceae to Restionaceae remains unresolved, as sister group or embedded within the latter, but there is some support for Centrolepidaceae embedded within Australian Restionaceae and sister to Leptocarpoideae. This highly distinctive clade may be recognised as subfamily Centrolepidoideae Burnett if included within Restionaceae. Tribe Haplantherae Benth. & Hook. f. has the same circumscription as Restionaceae, as currently recognised, and Restio Rottb. is designated as the lectotype of this tribal name.

Introduction

Restionaceae have been the subject of much detailed morphological, anatomical and evolutionary study but lack a classification of major infrafamilial groups that is consistent with current phylogenetic inferences. Relevant data have come from morphological studies (Linder 1984, 1985; Meney & Pate 1999; Linder et al. 2000), including anatomical (especially Cutler 1969) and palynological investigations (Chanda 1966, Chanda & Ferguson 1978, Linder & Ferguson 1985). Flavonoid constituents were investigated by Harborne (1979), Harborne et al. (2000) and Williams et al. (1998). Clearer indications of relationships have recently come from DNA-based phylogenetic investigations (Briggs et al. 2000; Linder et al. 2003, 2005; Hardy & Linder 2005, 2007; Linder & Hardy 2005; Moline & Linder 2005; Hardy et al. 2008; Briggs et al. submitted) which also confirmed that Centrolepidaceae was either closely related to Restionaceae or embedded within it.

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The phylogenetic hypotheses that are a basis for the suprageneric taxa recognised here are largely inferred from analyses of chloroplast DNA data which have proved more phylogenetically informative than study of the highly reduced vegetative structures and small wind-pollinated flowers. Indeed, homoplasious reduction in floral and vegetative structures has led morphological comparison often to produce erroneous conclusions. For example, the multiple losses of the distinctive and prominent culm anatomical feature of pillar cells in Australian Restionaceae only became apparent when a molecular phylogeny was developed (Briggs et al. 2000). More comprehensive morphological study, combined with DNA data has, however, added resolution to the phylogeny of the African members (Hardy et al. 2008).

When Restionaceae (as Restiaceae) was originally described by Robert Brown (1810) it was much more inclusive than the family now recognised. Diverse genera have been transferred to Anarthriaceae, Centrolepidaceae, Ecdeiocoleaceae, Eriocaulaceae or Xyridaceae. The separation of Anarthriaceae and Ecdeiocoleaceae was initially largely based on differences in their vegetative anatomy (Cutler & Airy Shaw 1965). DNA-based phylogenies (Briggs et al. 2000, Bremer 2002, Chase et al. 2006 and other studies in Columbus et al. 2006, Marchant & Briggs 2007, Briggs et al. in press) show Ecdeiocoleaceae to be more closely allied to Poaceae than to Restionaceae, whereas most DNA data show Anarthriaceae as sister to (Restionaceae plus Centrolepidaceae). While molecular data (Briggs et al. 2000) showed that *Lyginia* and *Hopkinsia* formed a clade with *Anarthria*, the recognition of the separate families Lyginiaceae and Hopkinsiaceae (Briggs & Johnson 2000) was based on the very divergent culm anatomy. However, an enlarged Anarthriaceae, including the three genera, is now generally accepted.

Centrolepidaceae Endl. (1836) **or Centrolepidoideae** Burnett (1835)

Centrolepidaceae have long been considered to be closely related to Restionaceae or a derivative of it (Dahlgren et al. 1985, Linder & Rudall 1993, Kellogg & Linder 1995, Linder et al. 2000) and together they form a robustly supported monophyletic group in chloroplast DNA studies of Poales (Briggs et al. 2000, Bremer 2002, Briggs et al. in press). Similarities in embryology have been especially noted (Hamann 1962, 1975, Prakash 1969, Rudall and Linder 1988, Linder & Rudall 1993), as well as the similarity of Centrolepidaceae plants to Restionaceae seedlings (Linder & Caddick 2001). Restionaceae, as in many other Poales, show a relatively fast rate of nucleotide substitution and long branches in molecular phylograms, but Centrolepidaceae have exceptionally long branches. Although the currently available plastid DNA sequence data (Briggs et al. in press) suggest that Centrolepidaceae is embedded in Restionaceae, as sister to Leptocarpoideae, the alternative arrangement as sister to Restionaceae cannot yet be convincingly rejected (Fig. 1).

If a position embedded within Restionaceae is accepted, this clade would be known as subfamily Centrolepidoideae Burnett (1835, page 416), see also Reveal (2007). Centrolepidoideae differ conspicuously from other Restionaceae in their diminutive size, sometimes annual habit, unreduced leaves, lack of perianth, and in the floral structures which have been regarded as pseudanthia of male flowers reduced to a single stamen and female flowers to a single carpel (Hamann 1962, 1975; Cooke 1998) but could also be highly modified flowers (Sokoloff et al. submitted). The pollen of Australian Restionaceae have been described as 'centrolepidoid' (Chanda 1966, Chanda & Rowley 1967, Ladd 1977, Chanda & Ferguson 1979, Johnson & Briggs 1981) but Linder and Ferguson (1985) drew attention to important features of Centrolepidaceae pollen such as the granular rather than columellate interstitium, lack of endexine and differences in the aperture and scrobiculi. *Centrolepis* (c. 26 spp., Cooke 1998), *Gaimardia* (4 spp.) and *Aphelia* (6 spp.) occur in southern temperate regions and mountains of the tropics: in Australia, south-east Asia, Pacific Islands and southern South America.

Major clades of Restionaceae

In addition to Centrolepidoideae, if included in Restionaceae, three major clades are now distinguished and here recognised as subfamilies: Sporadanthoideae and Leptocarpoideae are here newly described, along with Restionoideae (subdivided into two tribes, Restioneae and Willdenowieae). Relationships among the subfamilies are still not robustly resolved (Briggs et al. in press) but there is support for a clade of (Sporadanthoideae + Leptocarpoideae + Centrolepidoideae), with these either forming a trichotomy or grouped as (Sporadanthoideae (Leptocarpoideae + Centrolepidoideae)) (Fig. 1a). Thus the primarily Australian clade forms a sister group to the African Restionoideae. This topology is not supported by parsimony analyses of *trn*K and *trn*L-F data (Fig. 1b), but evidence from slowly evolving genes and from Bayesian or maximum likelihood analyses are considered more reliable in investigating ancient relationships (Jiang et al. 2008) than parsimony results from fast-evolving genes. The latter are more subject to artifacts arising from long-branch attraction.

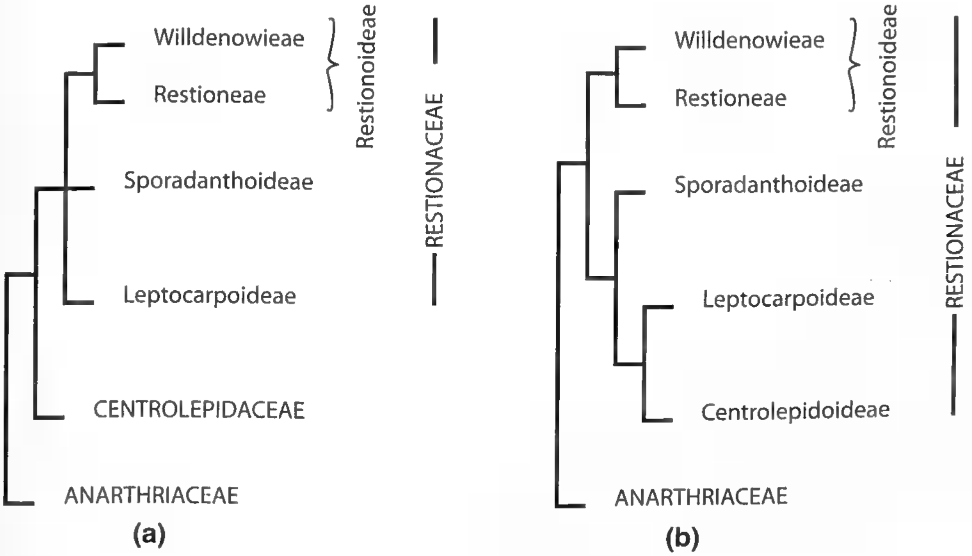

Fig. 1. Alternative positions of the centrolepid clade: (a) sister to Restionaceae (family Centrolepidaceae), as found from parsimony analysis of *trn*K or *trn*L–F; (b) embedded in Restionaceae (subfamily Centrolepidoideae) and sister to Leptocarpoideae, as found from *rbc*L data or from Bayesian analysis of *trn*K or *trn*L-F (Briggs et al. in press).

Previous subfamily and tribal nomenclature and classifications

The earliest valid use of names at subfamily and tribal rank based on *Restio* (Reveal 2007) are Restionoideae Link, Handbuch 1: 134. Jan-Aug 1829, and at tribal rank Restioneae Bartl., Ord. Nat. Pl.: 36. Sep 1830. These names are adopted here, as is Willdenowieae (Willdenovieae) Masters in A. DC., Monogr. Phan. 1: 314. Jun 1878. The circumscription of these taxa is, however, very different from when these names were first applied. In Bartling's treatment, Restioneae equates to the whole of Restionaceae (excluding Centrolepidaceae) as here recognised (examples from all major clades being included), whereas the two other subfamilies consisted of genera now placed in Centrolepidaceae, Anarthriaceae and Eriocaulaceae.

Haplantherae and Diplantherae. Bentham and Hooker (1883) divided Restionaceae, as then circumscribed, into two tribes: Haplantherae with one anther loculus and Diplantherae with two anther loculi. This classification was also used by Gilg-Benedict (1930),and these tribes were subsequently referred to as Restioneae and Anarthrieae (Hamann 1964). The latter tribe consisted of *Ecdeiocolea* F. Muell., *Anarthria* R.Br. and *Lyginia* R.Br. Subsequently *Ecdeiocolea* and *Anarthria* were excluded from Restionaceae with the description of Ecdeiocoleaceae and Anarthriaceae by Cutler and Shaw (1965). As mentioned above (Briggs et al. 2000), DNA data later showed that *Ecdeiocolea* is more closely allied to Poaceae than to Restionaceae and that *Lyginia, Hopkinsia* and *Anarthria* form a clade that is sister to (Restionaceae + Centrolepidaceae). So all members of Diplantherae are now excluded from Restionaceae.

Since Haplantherae has a circumscription equivalent to that of family Restionaceae, as the latter is now recognised, it is appropriate that it be typified by the same type. We therefore designate a lectotype.

Restionaceae tribe Haplantherae Benth. & Hook.f., *Genera Plantarum* vol. 3: 1028. Lectotype (here designated) *Restio* Rottb.

Restioideae and Willdenowieae. Masters (1878) recognised two tribes, Restioideae, with two or three (or one by abortion) ovary loculi and capsular fruit, and Willdenowieae (originally Willdenovieae) with a one-locular ovary and a nut fruit. These tribes formalised a grouping of genera largely based on the same criteria as that presented (without formal naming of groups) by Lindley (1836, p. 386), but which Lindley attributed to Nees von Esenbeck. Nees made important contributions to knowledge of Restionaceae (especially Nees 1830, 1846). The character of number of ovary loculi does not provide a satisfactory classification since there has been homoplasious reduction in carpel number in many groups within the clades now distinguished (Linder 1992a,b; Ronse Decraene et al. 2002).

When originally described, both of the tribes recognised by Masters included Australasian members as well as African ones. Indeed, it was only following the work of Gilg-Benedict (1930), Cutler (1969, 1972) and Linder (1984, 1985) that the names *Mastersiella* Gilg-Benedict and *Calopsis* Beauv. ex Desv. were adopted for African members, in contrast to the Australian *Hypolaena* R.Br. and *Leptocarpus* (Labill.) R.Br. More recently, the Australian taxa formerly included in *Restio* were separated from the African genus *Restio* (Briggs & Johnson 1998a, b), so that each of the genera now recognized can be assigned to the African clade or to one of the largely Australasian clades and subfamilies. This fulfils the prediction of Cutler (1972) that, when revised, no genus would be common to Australia and Africa. Our circumscription of tribes also shows no agreement with the classification of the African members by Pillans (1928), who included in Restionoideae only *Restio* and *Chondropetalum* (the latter now included in *Elegia*), placing all other genera in Willdenowieae.

Characters distinguishing subfamilies and tribes

Morphology. As a result of highly reduced structures and numerous homoplasious changes, neither external vegetative nor floral morphology offer features that we find useful in characterising the subfamilies, apart from Centrolepidoideae. Features are mostly not unique to a subfamily or are absent from some members of the subfamily, often by loss of the feature. For example, spikelet structure is widely found but in Sporadanthoideae the inflorescence is not always organised into spikelets: *Lepyrodia* and *Sporadanthus* lack spikelet structure, possibly having lost this feature, whereas *Calorophus* shows spikelet structure in both male and female inflorescences. However, lack of spikelet structure is not unique to Sporadanthoideae since, in Restionoideae, *Elegia* and males of *Willdenowia* do not have flowers aggregated into distinct spikelets.

Tribe Willdenowieae differs from Restioneae in that the pericarp is usually heavily lignified and the floral pedicel sometimes becomes thickened and functions as an elaiosome, and the gynoecium has two styles. Ronse Decraene et al. (2001) found a concordant pattern of loss of the anterior carpel and displacement of the remaining carpels throughout Willdenowieae, indicating that these aspects of floral development were synapomorphic. Linder (1992b) also found a single pattern of carpel development in the tribe, as well as a single origin of the hard, woody nutlet.

Pollen morphology. Pollen grains of the Sporadanthoideae and Leptocarpoideae are both of the type termed Australian restionoid (as 'Australian restioid') (Linder & Ferguson 1985), whereas the Restionoideae have African restionoid pollen. Thus pollen of the two Australasian subfamilies does not show the tectum raised around the large and usually irregular aperture, so that there is no distinct annulus; also there is no thickened foot layer. In the Restionoideae the tectum is raised around the relatively small aperture and some members have a thickened foot layer (Linder 1984, Linder et al. 1998).

Embryology. Proliferating antipodals were reported in Restioneae but were absent from those Sporadanthoideae and Leptocarpoideae studied (Rudall & Linder 1988). However, only a minority of genera have been sampled and there are no reports for Willdenowieae.

Culm anatomy. Differences in culm anatomy between African and Australasian members have long been recognised (Cutler 1969, Johnson & Briggs 1981, Linder 2000). Anatomical features are also reported for African members by Linder (1984) and Australian genera by Pate and Delfs (1999) and Meney et al. (1999).

Most of the following terms used for the distinctive anatomical cell types or structures were defined by Cutler (1969) who clearly recognised their taxonomic significance and pointed out differences between those Australian and African taxa that were at that time considered to be congeneric.

Protective cells: modified cells of the chlorenchyma with slightly to moderately thickened lignified walls surrounding a substomatal cavity forming a tube extending all or part way through the chlorenchyma. These occur in Restionoideae and Sporadanthoideae, being absent from Leptocarpoideae. Analogous protection of the substomatal cavity in members of the *Desmocladus* group and *Alexgeorgea* within Leptocarpoideae is by elongated and thick-walled epidermal cells. Using a broader definition of protective cells, Linder (2000) regarded epidermally-derived protective cells and chlorenchyma-derived protective cells as an example of convergence.

Pillar cells: elongate, palisade-like cells of the parenchyma sheath, usually with moderately thickened (lignified) walls, radiating from the sclerenchyma sheath to the epidermis, dividing the chlorenchyma into longitudinal bands. Since they arise from the parenchyma sheath, pillar cells are not homologous with '*false pillar cells*'. Pillar cells are restricted to Leptocarpoideae, and are present in *Eurychorda*, sister group to the rest of that subfamily, as well as in ten other leptocarpoid genera. However, there appear to have been homoplasious losses of this feature in at least four leptocarpoid clades (Briggs et al. 2000).

'*False pillar cells*' (Linder 1984, 2000) are lignified cells of the chlorenchyma that extend outwards from ridges of the sclerenchyma in some species. These are unique to the Willdenowieae, but are found only in a small minority of the species and genera.

Girders: sclerenchyma ridges opposite the outer vascular bundles, extending from the sclerenchyma sheath all or part-way through the chlorenchyma. These occur in Leptocarpoideae, although in only a few genera; they were designated as 'ribs opposite vascular bundles' by Linder (2000).

Ribs: sclerenchyma ridges alternating with the outer vascular bundles, extending from the sclerenchyma sheath all or part-way through the chlorenchyma (Cutler 1969, p. 327). They are a feature of most Willdenowieae.

Silica bodies: sphaeroidal-nodular bodies or granular sand may be present, especially in the parenchyma sheath (between the chlorenchyma and the sclerenchyma cylinder) or in the outer layer of the sclerenchyma. Silica bodies are absent from Anarthriaceae (Cutler 1969, Prychid et al. 2004). Such inclusions are widespread in the commelinid families, so presumably their loss is a synapomorphy of that family. Within Restionaceae, silica bodies are found in members of all subfamilies and tribes but are reported as absent from some genera, especially in the Restioneae (*Elegia*, *Staberoha*, *Rhodocoma*).

Phytochemistry. The subfamilies show significant differences in the flavonoid constituents of their culms (Harborne 1979, Williams et al. 1998, Harborne 2000, Harborne et al. 2000). Myricetin is reported only in Sporadanthoideae (present in *Lepyrodia* and *Sporadanthus*, although absent from *Calorophus*). Leptocarpoideae are characterised by flavones, commonly luteolin and hypolaetin, as well as sulphated flavonoid derivatives. Restionoideae show flavonols, commonly derivatives of myricetin and its methyl ethers larycitrin and syringetin, and also proanthocyanidins.

Description of subfamilies of Restionaceae

Sporadanthoideae B.G.Briggs & H.P.Linder, **subfam. nov.**

A Restionoideis et Leptocarpoideis combininatione characterum sequentium distinguenda: chlorenchyma continua, cellulis columnaribus nullis; parietes cellularum cavitates substomatales cingentes incrassati; flores in spiculis aggregati vel singulatim in inflorescentia portati; apertura pollinis ampla, irregularis, stratum fundum crassum deficiens.

Type genus: *Sporadanthus* F.Muell. Type: *Sporadanthus traversii* (F.Muell.) F.Muell. ex Kirk.

Flowers aggregated or not aggregated into spikelets; pollen with the tectum not raised around the large (8–25 µm) and usually irregular aperture and lacking a thickened foot layer (Australian restionoid type); proliferating antipodal cells in embryo sac lacking (so far as known); protective cells lining substomatal cavities present; chlorenchyma not interrupted by pillar cells or 'false pillar cells' or sclerenchyma girders or ribs; silica bodies or granular silica often present in epidermis and sometimes in ground tissue and parenchyma sheath; the flavonols myricetin and quercitin often present, flavones and protoanthocyanidins mostly absent.

A subfamily of three genera and about 31 species (including some not formally named), occurring in Australia and New Zealand. Sporadanthoideae equates with the *Lepyrodia* group of Briggs and Johnson (1999) and Briggs et al. (2000), but with the combined *Lepyrodia* and *Calorophus* groups of Johnson and Briggs (1981). The three genera recognized in the Sporadanthoideae, *Lepyrodia* R.Br. (species: 13 described, about 9 undescribed), *Sporadanthus* F.Muell. (7 described, 1 undescribed), and *Calorophus* Labill. (2 spp.), did not form a monophyletic group in a morphological cladistic study (Linder et al. 2000) but the clade is supported in most DNA analyses (Marchant & Briggs unpublished data).

Leptocarpoideae B.G.Briggs & H.P.Linder, **subfam. nov.**

A Restionoideis et Sporadanthoideis combininatione characterum sequentium distinguenda: chlorenchyma continua vel cellulis columnaribus vel costis schlerenchymatis interrupta; parietes cellularum cavitates substomatales cingentes non incrassati; flores in spiculis aggregati; apertura pollinis ampla, irregularis, stratum fundum crassum deficiens.

Type: *Leptocarpus* R.Br. (nom. cons.). Type (type. cons.): *L. tenax* (Labill.) R.Br.[1]

Flowers in spikelets; pollen lacking a thickened foot layer and the tectum not raised around the large (8–25 µm) and usually irregular aperture (Australian restionoid type); protective cells absent; pillar cells in the chlorenchyma present or absent; sclerenchyma girders mostly absent but when present opposite vascular bundles; 'false pillar cells' and sclerenchyma ribs absent; silica bodies often present in parenchyma sheath and epidermis; flavones luteolin and hypolaetin often present, flavonols and protoanthocyanidins mostly absent.

A subfamily with 28 genera currently recognised and about 117 species (including some not formally named), occurring in Australia, New Zealand, New Guinea, Aru Islands, Malesia, Hainan Island and Chile. Leptocarpoideae equates to the *Leptocarpus* group of Johnson and Briggs (1981) but to the combined *Winifredia*, *Desmocladus*, *Loxocarya* and *Leptocarpus* groups of Briggs and Johnson (1998a, 1999), together with

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[1] The proposal of this new conserved type (Briggs 2001, 2005) was recommended by the Committee for Spermatophyta (Brummitt 2005: p. 1096), endorsed by the General Committee (Barrie 2006: p. 800) and approved at the XVII International Botanical Congress (McNeill et al. 2005) but unfortunately the listing of the conserved type in the International Code of Botanical Nomenclature (Vienna Code) (McNeill et al. 2006: p. 270) was not changed to incorporate this decision. This oversight should be corrected in the next issue of the Code.

Alexgeorgea which was ungrouped. It also corresponds to the combined *Desmocladus*, *Loxocarya* and *Leptocarpus* clades of Linder et al. (2000) derived from morphological cladistic study.

The Leptocarpoideae are discussed by Briggs and Johnson (1999) and Meney and Pate (1999). The *Desmocladus* and *Leptocarpus* groups based on morphology of Briggs and Johnson (1998a, 1999) and Linder et al. (2000) are supported by DNA data but the *Loxocarya* group is paraphyletic and these groups do not adequately represent the main clades within Leptocarpoideae. Especially, the position of *Eurychorda* as sister-group to the remainder of Leptocarpoideae was not expected from morphological studies. The status of several genera is under review following results from analyses of DNA data.

Genera currently recognised: *Alexgeorgea* (3 species), *Apodasmia* B.G.Briggs & L.A.S.Johnson (3 described, 1 undescribed), *Baloskion* Raf. (8), *Catacolea* B.G.Briggs & L.A.S.Johnson (1), *Chaetanthus* R.Br. (3), *Chordifex* B.G.Briggs & L.A.S.Johnson (within which the previously described genera *Acion*, *Guringalia* and *Saropsis* [Briggs & Johnson 1998a] have been synonymised [Briggs & Johnson 2004]) (20), *Coleocarya* S.T.Blake (1), *Cytogonidium* B.G.Briggs & L.A.S.Johnson (1), *Dapsilanthus* B.G.Briggs & L.A.S.Johnson (4), *Desmocladus* Nees (15), *Dielsia* Gilg (1), *Empodisma* L.A.S.Johnson & D.F.Cutler (2), *Eurychorda* B.G.Briggs & L.A.S.Johnson (1), *Harperia* W.Fitzg. (4), *Hypolaena* R.Br. (8), *Kulinia* B.G.Briggs & L.A.S.Johnson (1), *Lepidobolus* Nees (6 described, 3 or 4 undescribed), *Leptocarpus* R.Br. (2 described, 1 undescribed), *Loxocarya* R.Br. (5), *Meeboldina* Suess. (5 described, 6 undescribed), *Melanostachya* B.G.Briggs & L.A.S.Johnson (1), *Onychosepalum* Steud. (3), *Platychorda* B.G.Briggs & L.A.S.Johnson (2), *Stenotalis* B.G.Briggs & L.A.S.Johnson (1), *Taraxis* B.G.Briggs & L.A.S.Johnson (1), *Tremulina* B.G.Briggs & L.A.S.Johnson (2), *Tyrbastes* B.G.Briggs & L.A.S.Johnson (1), *Winifredia* L.A.S.Johnson & B.G.Briggs (1).

Within Leptocarpoideae, pillar cells appear to be a pleisiomorphous character (Briggs et al. 2000), being present in eleven genera including *Eurychorda* which appears in molecular phylogenetic trees as sister to the remainder of the subfamily. The loss of pillar cells is, however, a homoplasy shown in the *Desmocladus* group (absent throughout), *Winifredia* group (pillars present in *Taraxis*; absent in *Empodisma* and *Winifredia*) and *Loxocarya* group (present in *Alexgeorgea*, western Australian *Chordifex*, *Dielsia*, *Eurychorda* and *Loxocarya*; absent in *Baloskion*, eastern Australian *Chordifex* (Briggs & Johnson 2004), *Cytogonidium*, *Dielsia*, *Melanostachya*, *Tremulina*, *Platychorda* and *Tyrbastes*). They are present throughout the *Leptocarpus* group.

Restionoideae Bartl.

Type: *Restio* Rottb. (nom. cons.) Lectotype: *Restio triticeus* Rottb. (McVaugh 1968).

Flowers mostly in spikelets; pollen with the tectum raised around the relatively small (4–10 μm) aperture and some members with thickened foot layer (African restionoid type); embryo sac often with proliferating antipodals; protective cells present lining substomatal cavities; pillar cells absent; sclerenchyma ribs sometimes present, alternating with outer vascular bundles; 'false pillar cells' sometimes present; silica bodies often present in the parenchyma sheath or the outer layer of the sclerenchyma cylinder; proanthocyanidins mostly present; glycosides of myricetin, larycitin and syringetin sometimes present.

A subfamily of about 350 species, occurring in sub-Saharan Africa and Madagascar, with principal diversity in the Cape Floristic Region of South Africa. Restionoideae comprises the African clade of Restionaceae, postulated to be a monophyletic group by Johnson and Briggs (1981) on the basis of morphological and anatomical features. Subsequently, morphological (Linder et al. 2000) and DNA studies (Eldenäs & Linder 2000, Linder et al. 2003, Briggs et al. in press) have corroborated its monophyly. Its morphology and members are described and discussed by Linder (1984; 1985; 1991a, b). Genera currently recognised are listed under the tribes.

Description of tribes within Restionoideae

Two tribes are recognised within Restionoideae, corresponding to the major clades apparent in most analyses of DNA data (Linder et al. 2003, Hardy et al. 2008, Briggs et al. in press). That the genera now placed in Willdenowieae formed a clade was also apparent from analyses of morphological data (Linder 1984, 1991b; Linder et al. 2000). Linder (1991b) observed that the *Willdenowia* clade is strongly supported by several unique morphological synapomorphies derived from a wide range of organs. The Restioneae, however, were not recognised as a clade (including *Staberoha* and *Ischyrolepis*) until molecular data were available.

Restioneae Bartl., Ord. Nat. Pl.: 36. Sep 1830.

Restioideae Mast. In A. & C. de Candolle, Monograph Phanerogamarum vol. 1: 218–398. 1878

All carpels fertile or variously reduced, styles 3, 2 or 1; fruits soft-walled nuts or capsules; young seed coat tanniniferous; pollen aperture various; sclerenchyma ribs absent; false pillar cells absent; chlorenchyma cells radially elongated; silica bodies often present in the parenchyma sheath but absent from the sclerenchyma.

Linder (1992b) found homoplasy in the patterns of carpel loss in the tribe, in contrast to the single pattern shown in the Willdenowieae. There was also evidence of multiple origins of unlignified nutlets in Restioneae. The evolution and ecology of members of the Restioneae have been investigated by Linder and Mann (1988), Linder and Hardy (2005), Hardy and Linder (2005), Linder et al. (2005) and Moline and Linder (2005).

A tribe of about 300 species, including many as yet undescribed species, Restioneae comprises the *Thamnochortus*, *Restio* and *Elegia* clades of Linder (1984). Genera currently recognised in Restioneae: *Askidosperma* Steud. (12), *Calopsis* Beauv. (23), *Elegia* L. (51, within which the previously recognised genera *Chondropetalum* Rottb. and *Dovea* Kunth have been synonymised [Moline & Linder 2005]), *Ischyrolepis* Steud. (c. 48), *Platycaulos* H.P. Linder (c. 8), *Restio* Rottb. (c. 93), *Rhodocoma* Nees (7), *Staberoha* Kunth (c. 9), *Thamnochortus* Berg. (33).

Analyses of chloroplast DNA data and morphology (Eldenäs & Linder 2000, Hardy et al. 2008) show that *Restio* and *Calopsis* are polyphyletic and changes to the generic classification are expected (Linder & Hardy in prep.).

Willdenowieae Masters in A. DC., Monogr. Phan. 1: 314. Jun 1878 (*Willdenovieae*).

Type: *Willdenowia* Thunb. Lectotype: *W. striata* Thunb. (Linder 1984: p. 67)

Mostly with a single functional carpel, and with carpels 2 and 3 fused; styles 2; young seed coat not tanniniferous; fruits mostly large woody nuts, often on fleshy pedicels; pollen aperture with foot layer scarcely thickened, border region ± sharply raised forming a very regular ring (aperture type 2b of Linder 1984); sclerenchyma ribs alternating with the outer vascular bundles mostly present; false pillar cells present or absent; chlorenchyma cells often radially short and squat; silica bodies usually present in the sclerenchyma.

A tribe of about 50 species, Willdenowieae equates to the *Ceratocaryum–Willdenowia* clade of Linder (1984) and many of the taxa are myrmechorous (Linder 1991a). Genera currently recognised in the Willdenowieae: *Anthochortus* Nees (15), *Cannomois* Beauv. ex Desv. (6), *Ceratocaryum* Nees (6), *Hypodiscus* Nees (15), *Hydrophilus* HPLinder (1), *Mastersiella* Gilg-Ben. (13), *Nevillea* Esterh. & H.P.Linder (2), *Willdenowia* Thunb. (12).

Molecular-based phylogenetic work (Eldenäs & Linder 2000, Hardy et al. 2008) suggests that a number of the genera are not monophyletic.

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Four new species related to *Bossiaea bracteosa* F.Muell. ex Benth. in south-eastern Australia

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Abstract

Bossiaea bracteosa F.Muell. ex Benth. has long been regarded as a widely distributed shrub, occurring in Victoria, New South Wales and the Australian Capital Territory. Most of its populations, however, are highly localised, poorly represented in herbaria and occur in disparate habitats. Following re-examination of herbarium collections and further collecting of isolated populations in New South Wales and the Australian Capital Territory, four species are here described as new: ***B. bombayensis*** K.L.McDougall, ***B. fragrans*** K.L.McDougall, ***B. grayi*** K.L.McDougall, and ***B. milesiae*** K.L.McDougall. The circumscription of *Bossiaea bracteosa* is emended and is here regarded as a Victorian endemic.

Introduction

Species of *Bossiaea* (Bossiaeeae: Fabaceae) lacking typical photosynthetic leaves are characterised by flattened branches (cladodes) and leaves that are reduced to scales. A recent review of *Bossiaea* in Western Australia (Ross 2006) identified five new taxa of leafless species in addition to the eight taxa that had previously been recognised. The variability in morphology and habitat within some other currently recognised species suggests that additional new taxa await elucidation.

In south-eastern Australia, many leafless Bossiaeas are extremely localised in their distribution and poorly represented in herbarium collections. One species, *Bossiaea bracteosa* F.Muell. ex Benth., characterised by its caducous bracteoles, has been regarded as occurring in Victoria, New South Wales (N.S.W.), and the Australian Capital Territory (A.C.T.). A population from Wombat Forest near Melbourne has recently been described as a new species, *B vombata* (Ross 2008). Most populations of *Bossiaea bracteosa*, as currently circumscribed, are highly disjunct and occur in a range of habitats: Australian Alps (Victoria; subalpine woodland), Snowy River (Victoria; habitat unknown), Bega area (N.S.W.; riparian), Murrumbidgee River (A.C.T.; riparian), Shoalhaven River (N.S.W.; riparian) and Abercrombie Caves (N.S.W.; dry woodland). Based on leaf scale length and general morphological characters, there are clear differences between populations of *Bossiaea bracteosa* from the Australian Alps (where the Type was collected) and other populations for which adequate herbarium

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material is available. Recent collections from N.S.W. and the A.C.T. have clarified the patterns of variation within older herbarium material of what has previously been classified as *B. bracteosa*, leading to the delimitation of four new taxa within this group. These are described below.

Diagnostic characters

In the species described below, some characters seem to have no diagnostic value or require further investigation before they can be reliably used to distinguish these taxa. For instance, all species are glabrous apart from minute hairs at the nodes, on the apices of floral bracts and on the inner surface of calyx lobes. Scattered, appressed hairs on young cladode branches are found in collections of all species except *B. fragrans* but little material of this species is available to confirm its diagnostic value. An exfoliating waxy coating has been noted in dried specimens of *B. bracteosa sens. lat.* (Ross 1996). This conspicuous feature seems to be common to all species except *B. milesiae*. However, it has limited diagnostic value because not all dried specimens within a species display this character.

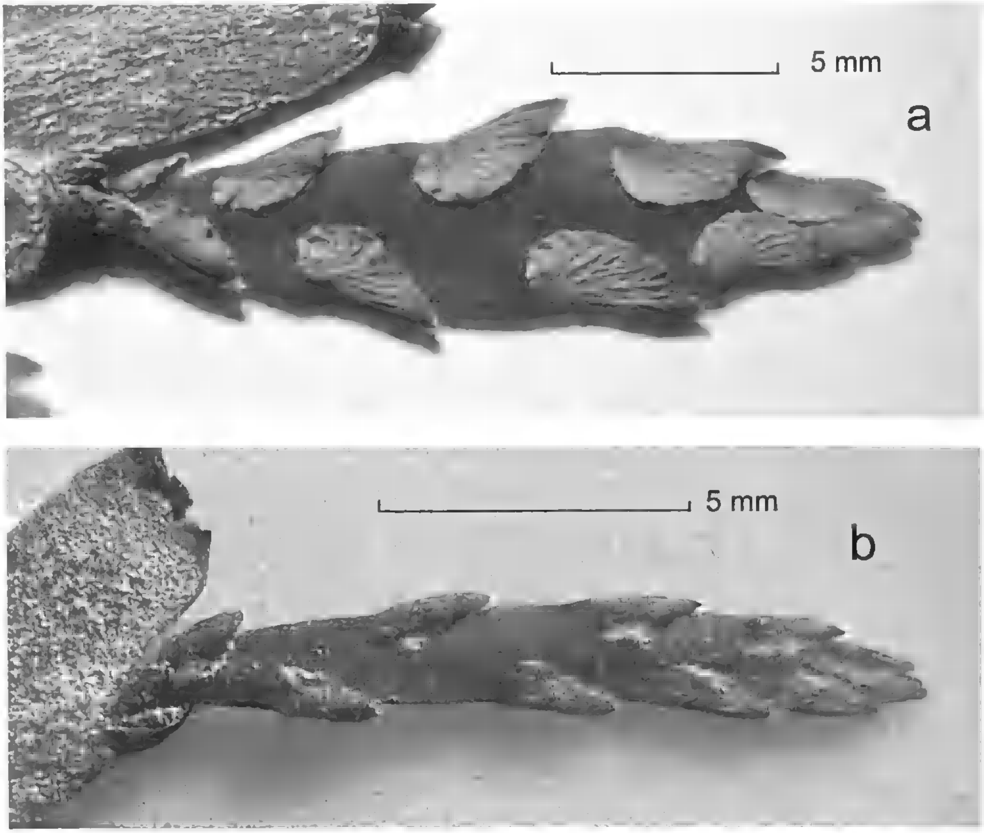

Fig. 1. Leaf scales on new cladode growth (undamaged). **a,** *Bossiaea bracteosa* (*N.G. Walsh 5716*) – long leaf scales with broad cordate bases and prominent venation; **b,** *Bossiaea grayi* (*K.L. McDougall 1272*) – short leaf scales with truncate bases and obscure venation

The most useful diagnostic characters are cladode size and colour; leaf scale size, shape, and venation; pedicel length; equality or not of calyx lobes; flower length and colour; staminal filament colour; and pod size and colour.

Cladodes

Reproductive cladodes are distinctive in width, margins and colour for most species. *Bossiaea bombayensis* has narrow, dark green, sub-flexuose reproductive cladodes that are predominantly red when young. *Bossiaea bracteosa* and *B. fragrans* have broad, glaucous-green reproductive cladodes. In these species, the margins are typically sinuate and the nodes are sometimes incised. *Bossiaea grayi* and *B. milesiae* have reproductive cladodes of intermediate width. Those of *B. grayi* are grey-green with straight margins (although slightly indented at the nodes), while those of *B. milesiae* are light green with straight to sinuate margins.

Leaf scales

Leaf scale length and venation is the principal character separating *Bossiaea bracteosa sens. strict.* from the other species. The leaf scales of *B. bracteosa* are > 2.5 mm long with broad cordate bases and prominent venation. The other species have relatively short leaf scales (generally < 1.5 mm long) with truncate bases and obscure venation (Fig. 1). Leaf scales are best viewed on young cladode branches because many become damaged or dislodged on older cladodes.

Flowers

Bossiaea bombayensis, B. bracteosa and *B. grayi* appear to have strictly one flower per node whereas *B. fragrans* and *B. milesiae* may have more than one. Multiple flowers seem to be common in *B. fragrans* but very rare in *B. milesiae.* Pedicels are short and hidden by floral bracts in *B. bracteosa, B. bombayensis* and *B. grayi*, and longer and exposed at flowering time in *B. fragrans* and *B. milesiae.* Floral bracts are largely persistent in *B. bracteosa, B. bombayensis* and *B. grayi*, whereas they are usually caducous in *B. fragrans* and *B. milesiae.* All but the outer few bracts, i.e. those closest to the cladode, are caducous in *B. fragrans* and *B. milesiae.* Calyx lobes are equal or subequal in *B. bracteosa, B. bombayensis* and *B. grayi* and distinctly unequal in *B. fragrans* and *B. milesiae.* The calyx of *B. bombayensis* is distinctively heavily tinged with red throughout, except for the tips of the lobes, which are golden brown. The calyces of other species tend to be green throughout. *Bossiaea bombayensis* has shorter corollas than the other species, whereas *B. fragrans* generally has the longest corollas. Although the external colour of the standard can be variable in *B. bracteosa, B. grayi* and *B. fragrans*, that of *B. bombayensis* is almost entirely red and that of *B. milesiae* is entirely yellow or apricot (apart from faint red striations). Staminal filaments are red in *B. grayi, B. fragrans and B. milesiae* or colourless or almost so in *B. bracteosa* (and sometimes *B. milesiae*) but the filaments of *B. bombayensis*, are distinctively alternately red and colourless.

Pods

Pod size differs between species (see dimensions below). However, abnormally small pods are common in all species and measurements should be made of a range of pods. Typical pods of *B. bombayensis* are smaller in length and width than other species and heavily tinged with red when immature.

Key to leafless Bossiaea with caducous bracteoles in eastern Australia

1 Flowers >15 mm long; keel longer than standard; ovules c. 20 .... ***B. walkeri***

1 Flowers <15 mm long; keel shorter than or ± equal to standard; ovules < 10 2

2 Upper 2 calyx lobes c. quadrangular contrasting strongly with the triangular lower lobes; pedicels exceeding floral bracts at flowering by 1–2 mm 3

2 Calyx lobes all triangular; pedicels not or hardly exceeding the floral bracts at flowering 4

3 Reproductive branches of cladodes mostly > 8 mm wide, becoming incised; standard 9–10 mm long; stipe of pods < 3 mm long; at least some nodes with > 1 flower .... ***B. fragrans***

3 Reproductive branches of cladodes mostly < 8 mm wide, not becoming incised; standard 7–9 mm long; stipe of pods ≥ 3 mm long; nodes rarely with > 1 flower .... ***B. milesiae***

4 Scales mostly 3–5 mm long .... ***B. bracteosa***

4 Scales mostly < 2 mm long 5

5 Corolla yellow or whitish, without any other coloration .... ***B. vombata***

5 Corolla with some purple, orange or red coloration as well as yellow 6

6 Cladodes dark green in fresh material; reproductive branches of cladodes usually < 4 mm wide; calyx lobes < 1.5 mm long .... ***B. bombayensis***

6 Cladodes grey green in fresh material; reproductive branches of cladodes usually > 4 mm wide; calyx lobes ≥ 1.5 mm long .... ***B. grayi***

1. ***Bossiaea bracteosa*** F.Muell. ex Benth., *Flora Australiensis* 2: 166 (1864).

Type: Victoria, Mitta Mitta (subalpine), *F. Mueller s.n., s.d.* (MEL 20333); lectotype *fide* A.T. Lee, *Contrib. New South Wales Natl. Herb.* 4:98 (1970).

Erect to spreading, suckering shrub 0.7–2 m high. Cladodes flattened, winged, becoming round or oval in cross-section; reproductive branches of cladodes oblong to narrowly ovate, green to glaucous-green, 7–12 mm wide, winged, rarely incised at the nodes, glabrous apart from minute hairs in the axils of the scale leaves and on the surface of new growth. Leaf scales 2.7–5 mm long, broadly ovate with cordate bases and acuminate to acute apices, reticulate venation prominent, glabrous apart from marginal cilia. Flowers 1 per node; pedicel 1.5–2 mm long, glabrous, obscured by floral bracts. Floral bracts imbricate, increasing in size from outer to inner, glabrous apart from marginal hairs, especially towards the apex, chestnut brown, the largest persistent bract c. 2.5 mm long with a broadly acute to obtuse, lacerated apex. Bracteoles caducous. Calyx glabrous apart from hairs on the margins and inner surface of the lobes apically, green, 4.5–5.5 mm long including 5 ± equal, triangular lobes 1.4–2 mm long, 1–1.3 mm wide. Corolla with standard 8.5–10 mm long including a claw 2.5–4 mm long, 10.5–11.5 mm wide, exceeding other petals, bright yellow to apricot internally with faint red striations, suffused with red externally; wings 7.5–9.5 mm long including a claw 3–4 mm long, yellow, glabrous; keel 7.5–9.5 mm long including a claw 3–4 mm long, dark red, glabrous. Ovary 5–6 mm long, (6–)8-ovulate, glabrous; style 4–5 mm long. Staminal filaments 3–4.5 mm long, ± colourless; sheath 4–6 mm long, ± colourless. Pods oblong, 2.3–3.2 cm long, 0.6–1 cm wide, glabrous, reddish brown when mature; stipe c. 2 mm long, obscured by remains of calyx. Seeds broadly elliptic to slightly reniform, 3–3.5 mm long, 1.5–2 mm wide, reddish brown to mid-brown.

Flowering: November—December (rarely in January).

Vernacular name: Mountain Leafless Bossiaea.

Selected specimens examined: Victoria: Eastern Highlands: Mountain Ash Spur between The Crinoline and Mount Skene, *J. Blackburn s.n.*, Dec 1950 (MEL 1529686); Black Range, 40 km NW of Maffra township, *J. Piggin s.n.*, May 1976 (CANB 602968); Snowfields: Mount Hotham area, *S.J. Forbes 410 & L. Ahern*, 20 Nov 1979 (MEL 594573, NSW 567293); c. 6 km SE of Hotham village on the Omeo Rd, *M.G. Corrick 7138*, 25 Jan 1981 (MEL 596957, NSW 567294).

Distribution and habitat: *Bossiaea bracteosa* is endemic to the Australian Alps of north-eastern Victoria (between elevations of 1000 and 1600 m), occurring mainly in the Dargo – Hotham area and the headwaters of the Macalister River (Fig. 2). It has been recorded in shrubby Snow Gum woodland, on shallow soils derived from sedimentary or basalt material.

Conservation status: this species is regarded as rare in Victoria but not necessarily threatened (Department of Sustainability and Environment 2005). Many collections note that it is common and most populations are in conservation reserves.

Notes: *Bossiaea bracteosa* is distinguished from the species described below by its prominent leaf scales, which have cordate bases and distinct venation. It is similar to *B. bombayensis* and *B. grayi* in having calyces with approximately equal lobes, persistent floral bracts and short, obscure pedicels but differs from those species in its relatively short and broad distal cladodes.

2. *Bossiaea bombayensis* K.L.McDougall, sp. nov.

B. bracteosae *F. Muell. ex Benth. affinis sed squamis foliorum brevioribus, cladodiis angustioribus, floribus et fructibus minoribus differt.*

Type: New South Wales: Southern Tablelands: Shoalhaven River, Bombay, 9 km W of Braidwood, *K.L. McDougall 1325* & *C.L. McDougall*, 10 Oct 2008; holo. NSW 777997; iso. CANB 778404, MEL 2312599.

Wiry shrub to 1 (–1.5) m high. *Cladodes* flattened, winged, glabrous apart from minute hairs in the axils of the scale leaves and scattered hairs 0.2–0.5 mm long on new growth, becoming round or oval in cross-section; reproductive branches of cladodes sub-flexuose, dark green (predominantly red when young), 2.3–4.5 mm wide, winged, not becoming incised at the nodes. *Leaf scales* 0.7–1.2 mm long, dark brown, glabrous apart from marginal cilia. *Flowers* solitary at the nodes; pedicels 1.5–2.5 mm long, glabrous, obscured by floral bracts. *Floral bracts* imbricate, dark brown to golden brown, mostly persistent, increasing in size from outer to inner, glabrous apart from marginal hairs, especially towards the apex, the largest of the persistent bracts 1.5–2 mm long with a broadly acute apex. *Bracteoles* caducous. *Calyx* glabrous apart from hairs on the margins and inner surface of the lobes apically (occasionally also on the outer surface of lobes), green with red spots, often heavily tinged with red abaxially, 4–5 mm long including the 5 ± equal, triangular lobes 0.9–1.4 mm long, c. 1 mm

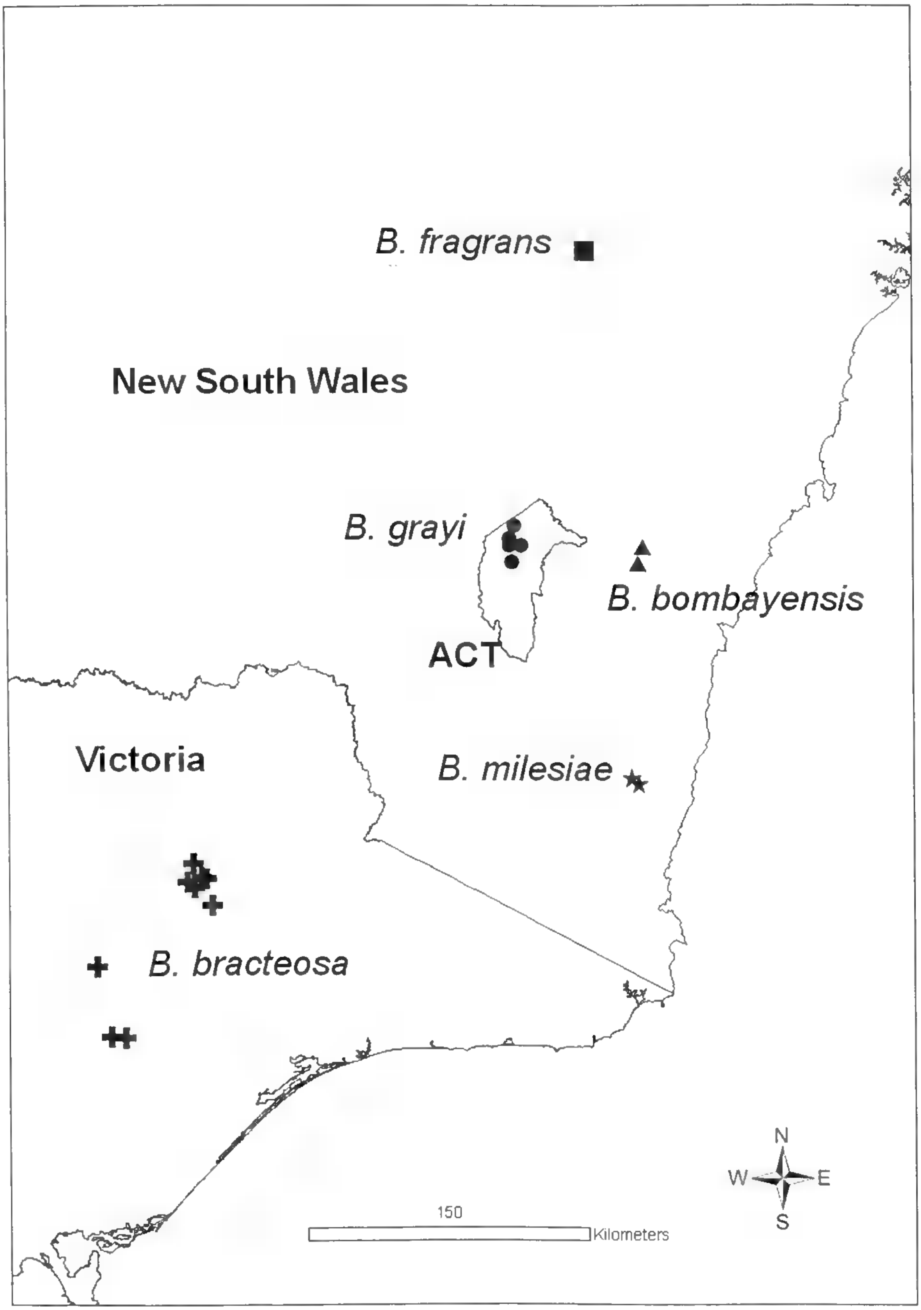

Fig. 2. Location of the five species of *Bossiaea* in south-eastern Australia.

wide, heavily tinged with red, often with golden brown tips. Corolla with standard 6.5–8 mm long including a claw 2–3 mm long, 9.5–11 mm wide, equal to or just exceeding other petals, deep yellow internally with red basal markings and faint red longitudinal striations radiating from the base to the edge of the lamina, predominantly deep red externally; wings 6.5–7.5 mm long including a claw 2.2–2.8 mm long, yellow, with red markings near base internally and externally, glabrous; keel 6.5–7.5 mm long including a claw 2.5–3 mm long, dark red with a pale base, glabrous. *Ovary* c. 5 mm long, 6–7(–8)-ovulate, glabrous; style 3.5–4 mm long. *Staminal filaments* 4–5 mm long, alternately red and colourless; sheath 3.5–4.5 mm long, colourless. *Pods* oblong, (1.4–)2–2.6 cm long, 0.4–0.6 cm wide, glabrous, red at first, ultimately dark green with thickened reddish-brown edges and red markings; stipe 1–2.5 mm long, obscured by remains of calyx. *Seeds* elliptic to subreniform, 2.3–2.5 mm long, 1.3–1.5 mm wide, pale brown with dark mottles (Fig. 3).

Flowering: September–October. Fruits dehisce: by mid-December.

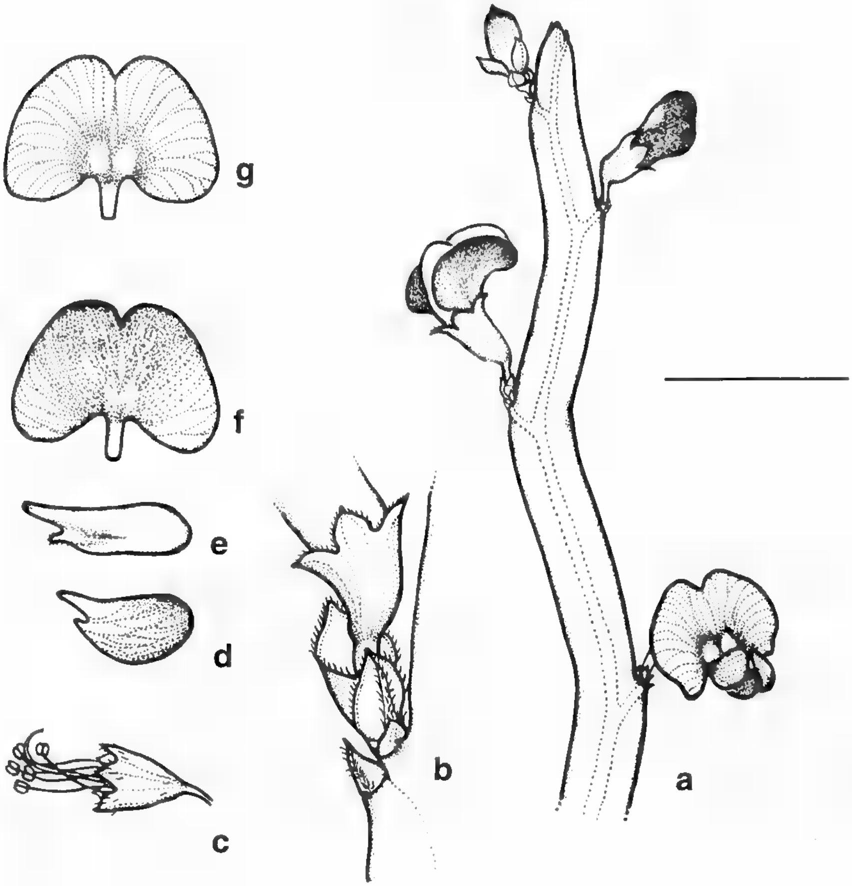

Fig. 3. *Bossiaea bombayensis*. **a**, cladode; **b**, floral bracts; **c**, calyx, stamens and style; **d**, keel; **e**, wing; **f**, standard (adaxial); **g**, standard (abaxial) (*K.L. McDougall 1200*). Scale bar: a, c–g = 10 mm; b = 15 mm.

Selected specimens examined: New South Wales: Southern Tablelands: Shoalhaven River, west of Braidwood, *R.H. Cambage s.n.*, 30 Oct 1908 (NSW 44157); Shoalhaven River, Warri Bridge, 13 km NNW of Braidwood, *M.D. Crisp 7724* & *I.R. Telford*, 14 Feb 1986 (CBG 8600454); Crown Reserve, Shoalhaven River, Bombay west of Braidwood, *K.L. McDougall 855*, 11 Oct 2000 (MEL 2097557); Shoalhaven River, Little Bombay, *K.L. McDougall 1198*, 21 Sep 2006 (NSW).

Distribution and habitat: *Bossiaea bombayensis* grows in a steeply incised valley of the Shoalhaven River, near Braidwood on the Southern Tablelands (Fig. 2). It is mainly found on sandy, rocky slopes and terraces above the frequent flood line in a shrubland of *Callitris endlicheri*, *Grevillea arenaria*, *Lomandra longifolia*, *Micrantheum hexandrum*, *Pomaderris andromedifolia* and *Leptospermum polygalifolium*. *Bossiaea bombayensis* rarely extends into dry sclerophyll woodland (comprising *Eucalyptus mannifera*, *E. rubida* and *E. dives*) on upper slopes above the river. Recruitment appears to be continuous as there is a range of plant sizes including seedlings. There have been no fires in this part of the Shoalhaven River valley in recent times so the species is not reliant on fire for regeneration. Scarification and dispersal of seed by floodwater may be important in the survival and spread of *B. bombayensis*.

Conservation status: although locally abundant, this species is restricted to a narrow, riparian corridor of about 12 km on the Shoalhaven River between Bombay and Warri, west of Braidwood. Competitive weeds (especially *Cytisus scoparius*, *Salix* spp. and *Rubus* spp.) are common and a significant threat to *Bossiaea bombayensis* and other native species along this section of river.

Etymology: *Bossiaea bombayensis* is named after the location in which most of the population is found. The Shoalhaven River at Bombay is a significant place of recreation for people of the Braidwood area and an important refuge for native flora and fauna within a largely cleared landscape.

Notes: *Bossiaea bombayensis* is distinguished from *B. fragrans* and *B. milesiae* by its equal to almost equal calyx lobes, from *B. bracteosa* by its much shorter, truncate leaf scales, and from *B. grayi* by its narrow, dark green cladode branches, smaller flowers and pods, alternating red and colourless staminal filaments, and general reddish appearance (of its flowers, new growth, calyx and pods).

3. *Bossiaea grayi* K.L.McDougall, sp. nov.

B. bracteosae *F. Muell. ex Benth. affinis sed squamis foliorum brevioribus et cladodiis angustioribus cinereis differt.*

Type: Australian Capital Territory: Murrumbidgee River, 1 km downstream from Kambah Pool, *I.R. Telford 8553*, Sep 1980; holo. CBG 8007070; iso. BISH 599975, MEL 641512, NSW 567291.

Erect shrub to 1.5 m high. *Cladodes* flattened, winged, glabrous apart from minute hairs in the axils of the scale leaves and scattered hairs on new growth, becoming round or oval in cross-section; reproductive branches of cladodes grey-green, linear, (3–)4–6 mm wide, winged, not becoming incised at the nodes. *Leaf scales* 1–2.2 mm long, dark brown, glabrous apart from marginal cilia. *Flowers* solitary at the nodes; pedicels 1–2 mm long, glabrous, obscured by floral bracts. *Floral bracts* imbricate, dark brown, mostly persistent, increasing in size from outer to inner, glabrous apart from marginal hairs, especially towards the apex, the largest of the persistent bracts c. 2.5 mm long with a broadly acute apex (often lacerated). *Bracteoles* caducous. *Calyx* glabrous apart from hairs on the margins and inner surface of the lobes apically, green, 5–6.5 mm long; lobes triangular, ± equal, 1.5–2.5 mm long, 1.2–1.5 mm wide, sometimes tinged with red. Corolla with standard 9.5–11 mm long including a claw 3–3.5 mm long, 11–12.5 mm wide, exceeding other petals, deep yellow internally with red basal markings and faint red longitudinal striations radiating from the base to the edge of the lamina, suffused with red externally; wings 9–10 mm long including a claw 3–3.5 mm long, yellow, with red markings near base, glabrous; keel 9–10 mm long including a claw 3–3.5 mm long, dark red, glabrous. *Ovary* 5–6.5 mm long, 6-ovulate, glabrous; style c. 4.5 mm long. *Staminal filaments* 3.5–4 mm long, tinged with red; sheath 4–5 mm long, mostly colourless. *Pods* oblong, 2–2.9 cm long, 0.6–1 cm wide, glabrous, dark reddish brown when mature; stipe 2.4–3.7 mm long. *Seeds* 2.8–3 mm long, 1.7–1.8 mm wide, tan to dark brown (Fig. 1).

Flowering: September–October. Fruit dehisces: December.

Selected specimens examined: Australian Capital Territory: Murrumbidgee and Cotter junction, *R.H. Cambage s.n.*, 5 Nov 1911 (NSW 44156); Molonglo River, directly south of Lower Molonglo Sewage Treatment Plant, *N. Taws 310 & A. Scott*, 18 Dec 1993 (CBG 9316417, MEL 2086950); Murrumbidgee River, 1 km downstream from Kambah Pool, *I.R. Telford 8553*, Sep 1980 (MEL 641512); west bank of Paddys River, *A.V. Slee 3123 & J. Johnston*, 3 Mar 1991 (CANB404588); cultivated, Australian National Botanic Gardens (Origin: Cotter Pumping Station), *K.L. McDougall 1271*, 24 Sep 2007 (NSW).

Distribution and habitat: known only from the banks of the Murrumbidgee River and its tributaries in the Australian Capital Territory (Fig. 2). *Bossiaea grayi* grows in sand amongst boulders on river banks dominated by *Casuarina cunninghamiana* or occasionally in shrubland of rock outcrops close to the river.

Conservation status: although this species has been recorded from several locations in the A.C.T. and, according to herbarium label notes, was locally common at some, it could not be found at any of the sites during surveys in spring 2006 and 2007. All sites were severely burnt in January 2003. The regeneration of exotic species (e.g. *Rubus* spp., *Conium maculatum*, *Eragrostis curvula*) was prolific after the fires and may have hindered the recruitment of *B. grayi*. Three small populations have since been located (Luke Johnston, A.C.T. Department of Parks, Conservation and Lands & Paul Carmen, Australian National Botanic Gardens, pers. comm.).

Etymology: the species is named in honour of Max Gray, retired CSIRO taxonomist, co-author of the "Flora of the A.C.T." and an early collector of this species. During my career, Max has given me invaluable encouragement and inspiration. As a homophone, the name is also highly descriptive of the cladode colour and general appearance of *B. grayi*.

Notes: *Bossiaea grayi* is distinguished from *B. fragrans* and *B. milesiae* by its equal to almost equal calyx lobes, from *B. bracteosa* by its much shorter, truncate leaf scales, and from *B. bombayensis* by its broader, grey green cladode branches, larger flowers and pods, and red staminal filaments.

In cultivation in the Canberra Botanic Gardens, *Bossiaea grayi* suckers vigorously. This behaviour was not evident in the wild, perhaps because of the lack of soil (and opportunity for suckering) in the one natural population seen.

A specimen from the Snowy River, in eastern Victoria (*L. Hodge s.n.*, Nov 1957, MEL 1529684) may also be *B. grayi*. This specimen is small and has only one flower with equal to almost equal calyx lobes and a pale-coloured standard. In its dimensions of cladode width, leaf scale length and flower length it is at the lower end of the range for *B. grayi*. Its identification will await relocation of the population and collection of good fertile material.

4. ***Bossiaea fragrans*** K.L.McDougall, **sp. nov.**

B. bracteosae *F.Muell. ex Benth. affinis sed squamis foliorum brevioribus, pedicellis longioribus, lobis calycis inaequalibus et floribus saepe ultra unum per axillam differt.*

Type: New South Wales: Central Tablelands: Abercrombie Karst Conservation Area, *K.L. McDougall 1268*, 21 Sep 2007; holo. NSW 785656; iso. CANB 766110, MEL 2318267.

Erect shrub 1–2.5 m high. *Cladodes* flattened, winged, becoming round or oval in cross-section but retaining remnants of wings; reproductive branches of cladodes glaucous green, oblong-linear to narrowly oblanceolate or irregular, (6–)8–14 mm wide, winged, glabrous apart from minute hairs in the axils of the scale leaves, becoming incised at the nodes. *Leaf scales* 1.5–1.9 mm long, dark brown, glabrous apart from marginal cilia. *Flowers* 1(–6) per node; pedicels 2.5–3 mm long, glabrous, exceeding persistent floral bracts by 1–2 mm at anthesis. *Floral bracts* imbricate, narrowly ovate, increasing in size from outer to inner, the largest of the persistent bracts c. 1.5 mm long with an acute apex, glabrous apart from marginal hairs, especially towards the apex, chestnut brown, all but a few bracts caducous prior to anthesis. *Bracteoles* caducous but rarely one or both present at anthesis. *Calyx* glabrous apart from hairs on the margins and inner surface of the lobes apically, green, 4.5–5 mm long; lobes c. 1 mm long, the 2 upper lobes c. 1.5 mm wide, rounded-truncate with acute, diverging apices, the lower 3 triangular, c. 1 mm wide, with acute apices. Corolla with standard 10.5–12 mm long including a claw 3–4 mm long, 12.5–15 mm wide, exceeding other petals, yellow internally and heavily tinged with red externally, with red basal markings and red longitudinal striations radiating from the base to the edge of the lamina; wings 10–11 mm long including a claw 3–4 mm long, yellow, with red markings near base and occasionally extending to edge of lamina, glabrous; keel 10–11 mm long including a claw 3–4 mm long, dark red, glabrous. *Ovary* 5.5–6 mm long, 5–6-ovulate, glabrous; style 2.5–4 mm long. *Staminal filaments* 4–5 mm long, red; sheath 4–5 mm long, red. *Pods* oblong, 2.4–3.8 cm long, 0.8–1 cm wide, glabrous, dark green with reddish-brown markings when mature; stipe 2.5–3 mm long. *Seeds* elliptic to sub-reniform, 3.0–3.2 mm long, 1.8–2 mm wide, dark brown (Fig. 4).

Flowering: September–October. Fruits dehisce: by December.

Specimens examined: New South Wales: Central Tablelands: Abercrombie Caves, *E.F. Constable s.n.*, 24 Mar 1955 (NSW44119); Abercrombie Caves, east of Grove Creek, *K.L. McDougall 999 & D. Monahan*, 25 Oct 2001 (MEL 2210156); Abercrombie Caves, east of Grove Creek, *K.L. McDougall 1270*, 21 Sep 2007 (NSW 785652).

Distribution and habitat: known from two populations in Abercrombie Karst Conservation Area, south of Bathurst (Fig. 2). The species occurs in open White Box (*Eucalyptus albens*) woodland. Despite their occurrence near Abercrombie Caves, a limestone feature, the populations occur on slate and volcanic substrates. Seeds are heavily predated by insects and few pods have been found with fully developed seeds.

Conservation status: there are currently fewer than 20 plants known of this species. The populations are threatened by competition from the introduced grass Serrated Tussock (*Nassella trichotoma*) and grazing by goats.

Etymology: the epithet of this species refers to its fragrant flowers. This feature was very obvious when sample bags containing specimens were opened. Collections of other leafless Bossiaeas from the A.C.T. and N.S.W. that I have made have not displayed this attribute. The diagnostic value of this character is uncertain but the fragrance of the *B. fragrans* collections was very strong and pleasant.

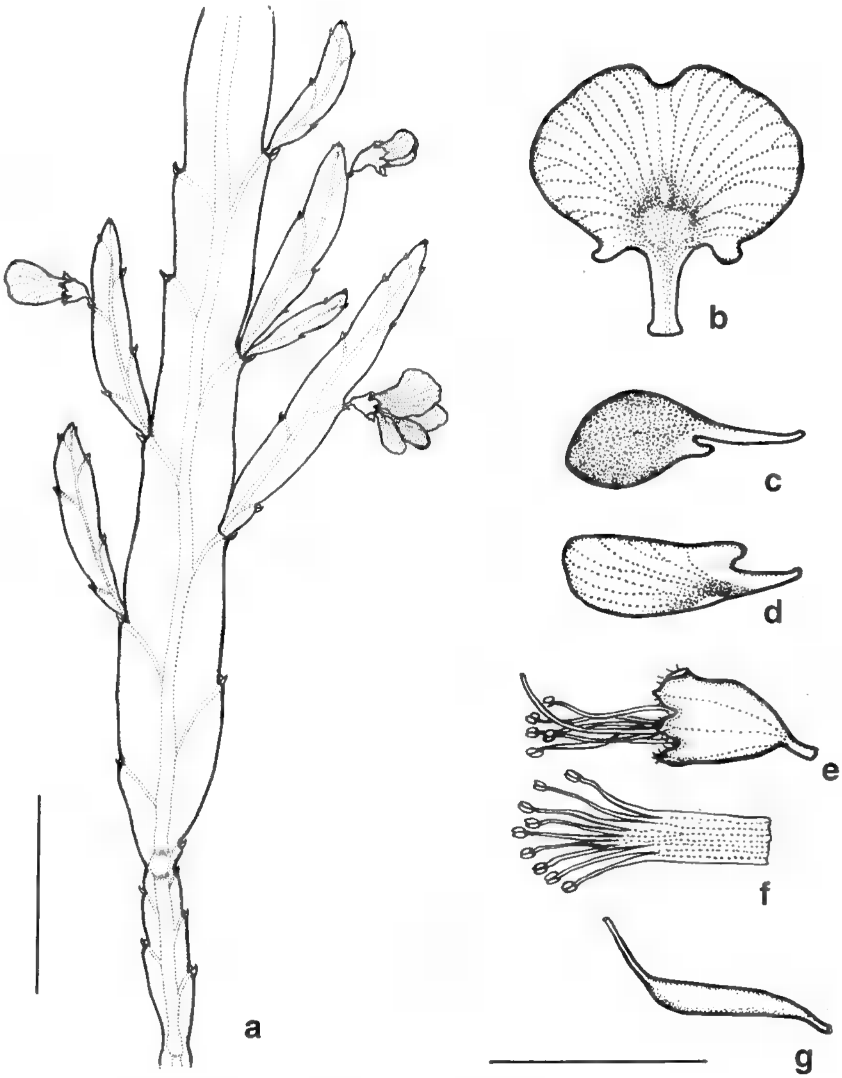

Fig. 4. *Bossiaea fragrans.* **a,** cladodes; **b,** standard; **c,** keel; **d,** wing; **e,** calyx, stamens and style; **f,** staminal filaments and sheath; **g,** ovary (*K.L. McDougall 1268*). Scale bar: a = 20 mm; b–g = 10 mm.

Notes: of the five taxa described in this paper, *Bossiaea fragrans* is most similar to *B. milesiae* in having asymmetrical lobes, longer pedicels and largely caducous floral bracts. It differs from *B. milesiae* in its broader, glaucous cladode branches, longer corollas and darker coloured standards. The two species also occupy very different habitat.

One collecton of *B. fragrans* (*K.L. McDougall 1270*), made in 2007 from a population containing a single plant, has as many as six flowers per node. Some flowers of this collection are also irregular (e.g. with two ovaries and corollas per calyx, with four wings or with a wing fused to the calyx). Collections in the same year from plants of a second, larger population, however, had only 1 or 2 flowers per node. Type material (*K.L. McDougall 1268*) for this species was taken from the second population.

The collection by Constable (NSW 44119) describes plants as being 1.8–2.8 m in height. The tallest extant plant is about 1.3 m tall while most are less than 1 m in height.

5. *Bossiaea milesiae* K.L.McDougall, **sp. nov.**

B. bracteosae *F. Muell. ex Benth. affinis sed squamis foliorum brevioribus, pedicellis longioribus, floribus majoribus saepe luteis et lobis calycis inaequalibus differt.*

Type: New South Wales: South Coast: Brogo River, c. 25 km NNW of Bega (c. 1 km downstream from Brogo Dam), *K.L. McDougall 1193, J. Miles & P. Jeuch*, 12 Sep 2006; holo. NSW 785654; iso. CANB 766111, MEL 2318264.

Shrub to 2 m high. *Cladodes* flattened, winged, glabrous apart from minute hairs in the axils of the scale leaves (and scattered hairs on new growth), becoming round or oval in cross-section; reproductive branches of cladodes light green, oblong-linear to narrowly oblanceolate, 4–8(–10) mm wide, winged, not becoming incised at the nodes. *Leaf scales* 1.2–1.8 mm long, glabrous, dark brown apart from marginal cilia. *Flowers* 1(–3) per node; pedicels 2.5–3 mm long, glabrous, exceeding persistent floral bracts by 1–2 mm. *Floral bracts* imbricate, narrowly ovate, increasing in size from outer to inner, the largest of the persistent bracts c. 1.5 mm long with an acute apex, glabrous apart from marginal hairs, especially towards the apex, chestnut brown, all but a few of the bracts caducous prior to anthesis. *Bracteoles* caducous. *Calyx* glabrous apart from hairs on the margins and inner surface of the lobes apically, bright green, 4.5–5.3 mm long; lobes 1–1.2 mm long, the 2 upper lobes c. 1.5 mm wide, rounded-truncate with acute, diverging apices, the lower 3 triangular, c. 1 mm wide, with acute apices. Corolla with standard 9.5–11 mm long including a claw 3.5–4 mm long, c. 12 mm wide, exceeding other petals, deep yellow to apricot internally with red basal markings and distinct red longitudinal striations radiating from the base to the edge of the lamina, yellow to apricot externally; wings 8.5–10 mm long including a claw 2.5–3.5 mm long, yellow, with red markings near base internally, glabrous; keel 9–10 mm long including a claw 3–3.5 mm long, red with a pale base, glabrous. *Ovary* 5–5.5 mm long, 6–7-ovulate, glabrous; style 3.5–4 mm long. *Staminal filaments* 3.5–4.5 mm long, red towards the stamens; sheath 4–5 mm long, colourless. *Pods* oblong, 2.7–3.5 cm long, 0.7–0.9 cm wide, glabrous, dark reddish-brown when mature; stipe 3–4.7 mm long. *Seeds* elliptic to subreniform, 2.5–3.5 mm long, 2–2.5 mm wide, tan (Fig. 5).

Flowering: August–September. Fruits dehisce: December–January.

Selected specimens examined: New South Wales: South Coast: Lower banks of Brogo River, 0.5 km downstream from wall of Brogo Dam, *J. Miles s.n.*, 9 Sep 1997 (MEL 2040660); upper end of Brogo Dam on banks of Brogo River, *J. Miles s.n.*, 29 Dec 2001 (MEL 2114662).

Distribution and habitat: *Bossiaea milesiae* appears to be confined to the Brogo River catchment near Bega (South Coast) in the vicinity of Brogo Dam (Fig. 2). It is locally abundant in riparian vegetation at the break of slope above the river and, in places, in the rocky and sandy river beds. Associated species include *Acacia mearnsii, Allocasuarina littoralis, Angophora floribunda, Bursaria spinosa, Eucalyptus viminalis, Eucalyptus tereticornis, Imperata cylindrica, Lomandra longifolia* and *Tristaniopsis laurina* (Jackie Miles, pers. comm.).

Conservation status: rare but not obviously threatened at present. Locally abundant.

Etymology: *Bossiaea milesiae* is named after Jackie Miles, a botanist from Brogo, who alerted me to this species. Jackie has made numerous collections from south-eastern N.S.W. and contributed greatly to knowledge about rare and threatened plants in this region.

Notes: *Bossiaea milesiae* differs from *B. bombayensis, B. bracteosa* and *B. grayi* in having unequal calyx lobes. From *Bossiaea fragrans* it is distinguished by it narrower, green cladode branches, shorter corollas and the absence of red markings on the outer surface of the standard.

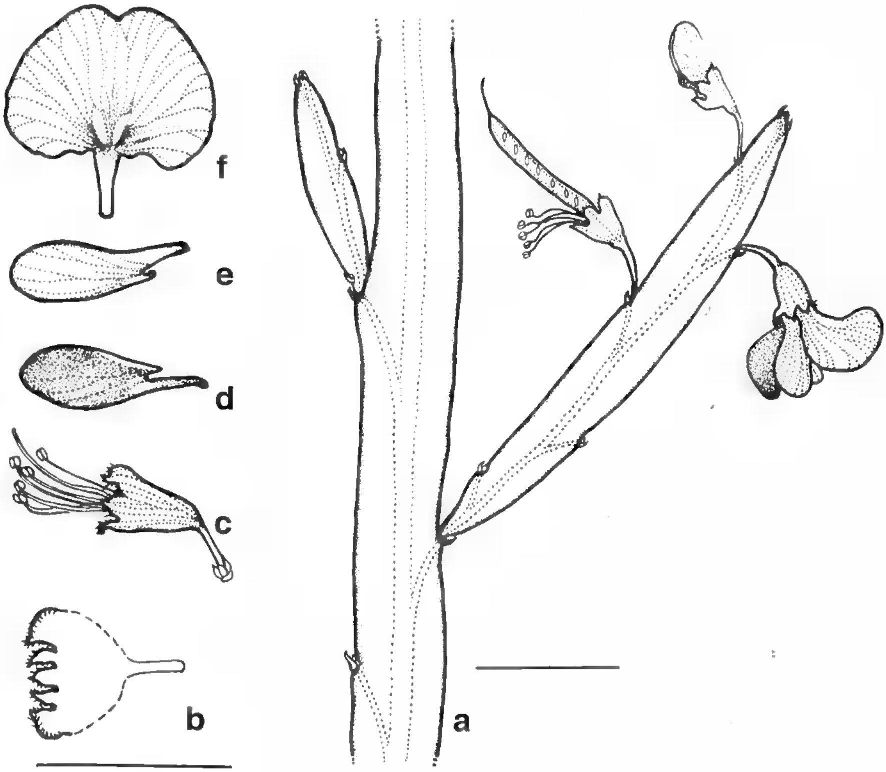

Fig. 5. *Bossiaea milesiae.* **a,** cladode; **b,** calyx (opened); **c,** calyx, stamens and style; **d,** keel; **e,** wing; **f,** standard (*K.L. McDougall 1194*). Scale bar: a = 10 mm; b–f = 10 mm.

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A new genus *Austrohondaella* (Bryopsida, Hypnaceae) from Australasia

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Abstract

The taxonomic position of *Isopterygium limatum* (Hook.f. & Wilson) Broth. has been re-evaluated. Some morphological characters, such as cylindric capsules, conic and non-rostrate opercula, well-differentiated annuli, pseudoparaphyllia shape, and axillary, papillose rhizoids suggest that the species should be excluded from the genus *Isopterygium*. A new genus, *Austrohondaella* Z.Iwats., H.P.Ramsay & Fife is therefore described here for *Isopterygium limatum*. This new genus should be classified in the family Hypnaceae.

Introduction

During studies on the genus *Isopterygium* for the floras of Australia and of New Zealand, it was noted separately by Fife and Iwatsuki that certain characteristics such as the erect capsule and operculum form, presence of an annulus, form of pseudoparaphyllia, and axillary and papillose rhizoids in *Isopterygium limatum* were not characteristic of the genus *Isopterygium* as outlined by Iwatsuki (1970, 1987) and Iwatsuki and Ramsay (2009). The common morphological features such as lanceolate leaves with a usually entire leaf margin, papillose axillary rhizoids and a differentiated annulus suggest that it might be a species of *Isopterygiopsis* (Fife in Seppelt 2004: 186). However, other features of *I. limatum* such as its erect capsules, bluntly conic opercula, narrowly foliose pseudoparaphyllia, etc are not consistent with this suggestion.

Sporophytic characters of *I. limatum* are quite different from those of both *Isopterygium tenerum*, the lectotype species for the genus *Isopterygium*, and *I. albescens* which is widely distributed in Australasia, eastern Asia and Oceania. In the genus *Isopterygium*, erect and almost symmetrical capsules occur only in *I. limatum*. However, erect symmetrical capsules are not rare in Hypnaceae; for example, some species of *Hondaella, Platygyrium, Pylasia*. Species of *Isopterygium* s.s., including *I. albescens* and *I. tenerum*, lack a differentiated annulus and have apiculate or obliquely short-rostrate opercula while *I. limatum* has both a well differentiated and deciduous annulus of 2 or 3 rows of cells and a bluntly conic operculum.

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Some gametophytic characters of *Isopterygium limatum* are also clearly anomalous in the genus *Isopterygium*, according to the criteria set out by Iwatsuki (1987) and cited in Ireland (1991). Species of *Isopterygium* have filamentous pseudoparaphyllia, while *I. limatum* has narrowly foliose pseudoparaphyllia, similar to those of species of *Ectropothecium*. The leaves of *I. limatum* are characteristically strongly secund giving the species something of the appearance of *Hypnum*, while those of *Isopterygium* are usually more or less complanate, erect spreading or only moderately secund. Rhizoids commonly arise on stems between leaf insertions and are smooth in most species of *Isopterygium* whereas they are axillary and papillose in *I. limatum*. These differences are significant enough to require a new genus for this interesting moss, and we propose the name *Austrohondaella*.

The new monotypic genus *Austrohondaella* shares some common characters with *Hondaella*, a genus of Hypnaceae recorded from eastern Asia (Japan, China, Korea, Laos, Myanmar, Thailand, and Russia). Illustrations of the type species of *Hondaella*, *H. aulacophylla* Dixon & Sakurai (= *H. brachytheciella* (Broth. & Paris) Ando) are available in Sakurai (1938) and Noguchi (1994). Species of *Hondaella* and *Austrohondaella* have erect capsules, similar leaf shape, entire leaf apices, hypnaceous peristomes, etc. However, the pseudoparaphyllia of *Hondaella* are much larger, and wider, than those of *Austrohondaella*. Moreover, the annulus is not differentiated, and leaves are truncate at the base in *Hondaella*.

Austrohondaella Z.Iwats., H.P.Ramsay & Fife, **gen. nov.; fam. Hypnacearum**

Plantae mediocres dioicae; caulis prostratus; stratum corticale e cellulis incrassatis compositum; rhizoidea papillosa axillariaque; folia anguste ovato-lanceolata; nervis binis brevissimus; pseudoparaphyllia anguste foliosa; alae foliorum non decurrentes; cellulae foliorum angustissime prosenchymaticae; thecae ovoideae; annulus distinctus; operculum conicum.

Type species: *Hypnum limatum* Hook.f. & Wilson, *Fl. Antarct. 2* (Suppl.): 545 (1847); *Isopterygium limatum* (Hook.f. & Wilson) Broth., *Nat. Pflanzenfam.* 1(3): 1080 (1908).

Etymology: the generic name reflects the morphological similarities to the Asian genus *Hondaella* and the Australian/New Zealand distribution of the type species.

Plants dioicous. Stems creeping, irregularly branched, epidermal cells small and more or less thick-walled in cross-section; pseudoparaphyllia narrowly foliose, base 2 or 3 cells wide. Rhizoids axillary, red, papillose. Leaves narrowly lanceolate, often falcate to falcate-secund, base rounded, not decurrent; upper portion of leaf gradually narrowed to piliferous apex; costa weak and short, often absent; cells in median portion of lamina linear to subvermicular; basal cells shorter. Perichaetia lateral on stems; perichaetial leaves lanceolate, entire, ecostate with apex narrowly acute. Setae long exserted; capsules cylindrical, erect, mostly symmetrical, sometimes slightly asymmetrical; operculum bluntly conic, apex obtuse; annulus well developed; peristome teeth hypnaceous.

Austrohondaella limata (Hook.f. & Wilson) Z.Iwats., H.P.Ramsay & Fife, **comb. nov.**

Hypnum limatum Hook.f. & Wilson, *Fl. Antarct.* 2 (Suppl.): 545 (1847). Type: Campbell's Island, Antarct. Exp. 1839–1843, *J. D. Hooker*; holotype BM (*n.v.*); isotype: NY. *Isopterygium limatum* (Hook.f. & Wilson) Broth., *Nat. Pflanzen.* 1(3): 1080 (1908).

Hypnum terrae-novae Brid. var. *australe* Hook.f. & Wilson, *Fl. Antarct.* 1: 142 (1845).

Ectropothecium australe (Hook.f. & Wilson) A.Jaeger, *Ber. S. Gall. Naturw. Ges.* 1877–78: 260 (1880) *nom. illeg. incl. spec. prior.*

Leskea amblyocarpa Hampe, *Linnaea* 30: 638 (1860). Type: Victoria, Apollo Bay, *F. Mueller 50*; holotype: BM. *Isopterygium amblyocarpum* (Hampe) Broth., *Nat. Pflanzenfam.* 1(3): 1080 (1908). syn. nov.

Isopterygium acuminatum Bosw., *J. Bot.* 30: 99 (1892). Type: Tasmania, Glen Rae, 1891, *W.A. Weymouth* [555]; holotype: HO 73037; isotype: NY. *syn. nov.*

Illustrations: Hooker (1847, Plate LXI, fig. IV, as *Hypnum terrae-novae*); Sainsbury (1955, Plate 74, fig 3, as *Isopterygium limatum*); Seppelt (2004, fig. 74, as *Isopterygium limatum*).

Plants dioicous, yellow or golden-green, glossy, forming dense mats. Stems creeping, 1–2 cm long, irregularly branched; branches short, usually up to 5 mm long. Cross-sections of stem round to more or less triangular, 0.1–0.2 mm in diam., epidermal cells small and more or less thick-walled, central strand present but often weak. Pseudoparaphyllia narrowly foliose, 2–4 cells wide at base. Rhizoids axillary, restricted to lower stems near base of branches, red, papillose. Leaves narrowly lanceolate to ovate-lanceolate, secund and usually falcate, 1.0–1.5(–1.8) mm long, 0.25–0.75 mm wide at base, base rounded, not decurrent, slightly concave; upper portion of leaf tapering evenly, narrowed to acuminate to piliferous apices; costa weak and double or often absent; margin entire; cells in median portion of lamina linear to subvermicular, 60–120 µm long, 5–8 µm wide, narrow at both ends, moderately thick-walled, not porose; cells at base of leaves wider and shorter, becoming porose; alar cells not differentiated. Propagules, when present, axillary and filamentous or ± fusiform.

Perichaetia lateral on stems; perichaetial leaves lanceolate, narrowly acute at apices, to 1.7 mm long, 0.38 mm wide; ecostate, entire; laminal cells elongate and moderately thick-walled. Calyptra large, cucullate, c. 3 mm long. Setae 1.0–1.5 cm long, reddish brown. Capsules cylindrical, erect, often slightly to clearly asymmetrical, urn about 2 mm long; operculum bluntly conic; annulus well developed, deciduous; exothecial cells rectangular, 25–50 µm long, c. 20 µm wide, moderately thin-walled. Peristome double, hypnaceous; outer teeth c. 1mm long; endostome segments a little shorter than outer teeth; cilia 1 or 2, nodose, equal to the segments or rudimentary. Spores spherical, 10–18 µm in diam., smooth. No chromosome number recorded. Figs 1–4.

Distribution: Australia (New South Wales (alpine), Victoria, Tasmania and Macquarie Is) and New Zealand (North, South, Stewart, Auckland and Campbell Is.). In Australia *Austrohondaella* occurs in scattered pure and dense mats on dolerite karst and also on basalt where it is found on moist exposed rock faces and in crevices. Also, it is occasionally epiphytic on semi-shaded tree trunks (e.g. *Acacia*, *Pomaderris* and tree ferns) and on fallen logs in disturbed *Nothofagus* or wet sclerophyll forest. On the mainland it occurs from 80–1700 m, while on the island of Tasmania is recorded from 20–1000 m. In New Zealand it occurs in scattered or dense mats primarily on mesic or rather dry rock, but in the northern and southern portions of its range it also occurs on tree trunks. It is best developed in montane to alpine vegetation. *Austrohondaella limata* occurs on a wide range of rock types but is most frequent on limestone and marble; it occurs less frequently on greywacke, basalt, conglomerate, granite, diorite and on humus. When epiphytic at the extremities of its range the host species include the gymnosperms *Prumnopitys taxifolia* and *Dacrydium cupressinum*, as well as

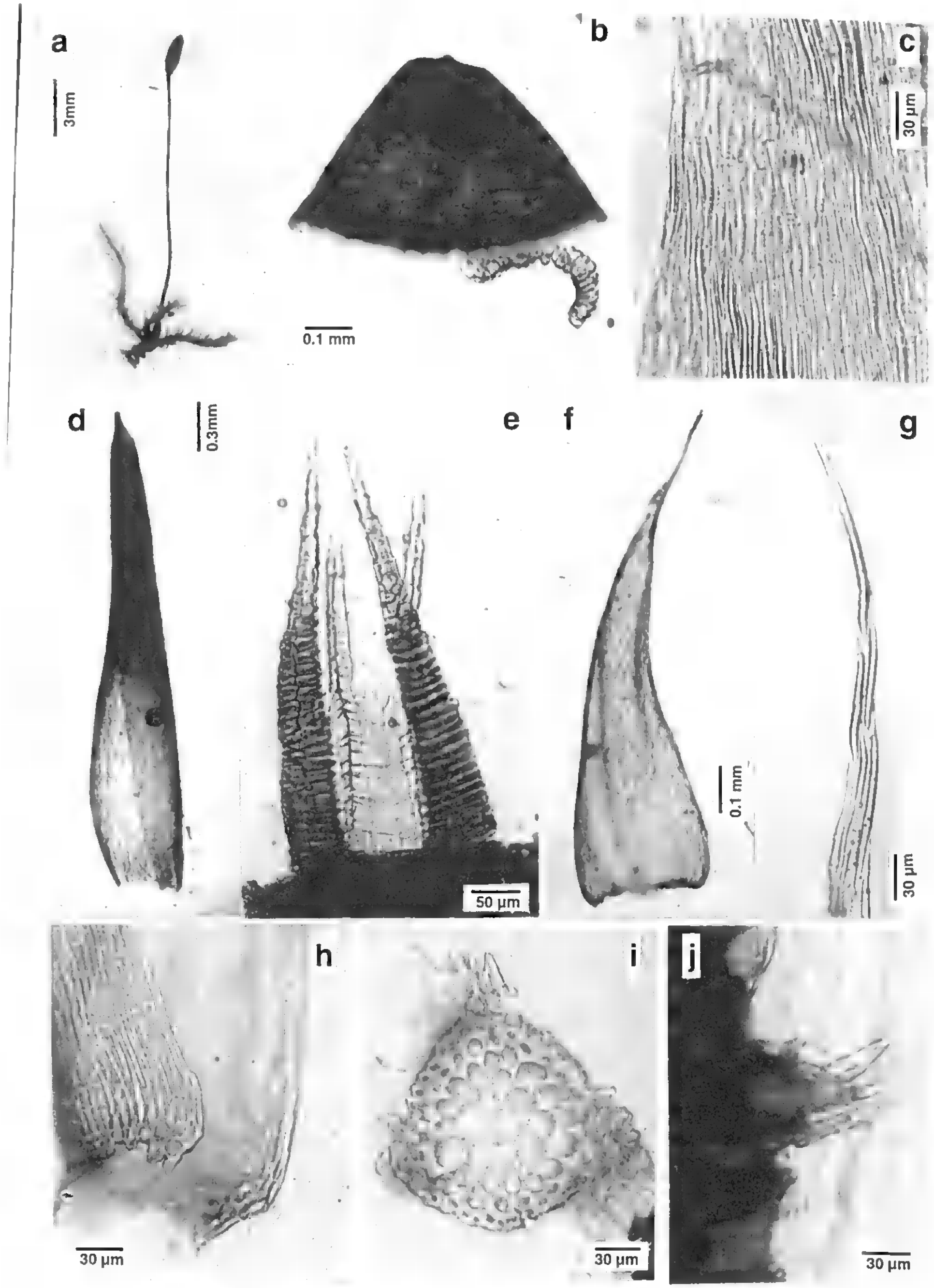

Fig. 1. *Austrohondaella limata.* **a,** type plant of *Hypnum limatum* with sporophyte; **b,** operculum with a part of annulus; **c,** median laminal cells of type; **d,** calyptra; **e,** peristome teeth and rudimentary cilia; **f,** a leaf; **g,** apex of leaf; **h,** cells at base of leaf; **i,** cross-section of stem; **j,** pseudoparaphyllia. (a, c, f, g, i and j from the isotype of *Hypnum limatum* in NY; b, d, e and h. from *H. Streimann 58986* in NICH; all photographs by Z. Iwatsuki).

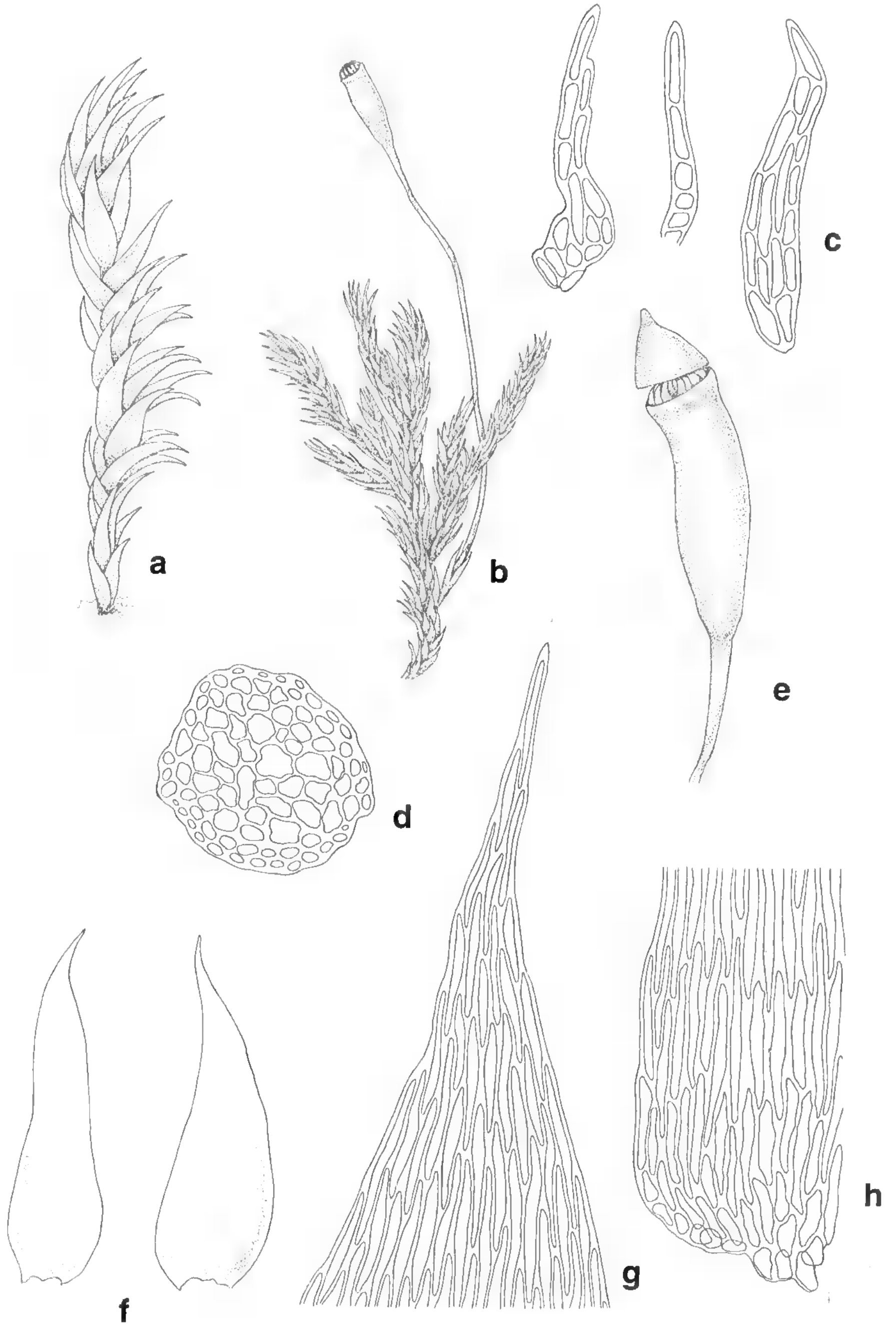

Fig. 2. *Austrohondaella limata.* **a,** sterile shoot; **b,** portion of fertile plant; **c,** pseudoparaphyllia; **d,** stem in cross section; **e,** moist capsule with operculum; **f,** stem leaves; **g,** apex of stem leaf; **h,** alar cells of stem leaf. (a, b, d–h from *J. Child 6212* ex Otago Peninsula, N.Z. (CHR 429281); c from *A.J. Fife 7546* ex Mt Arthur range (CHR 438862); drawn by Rebecca Wagstaff).

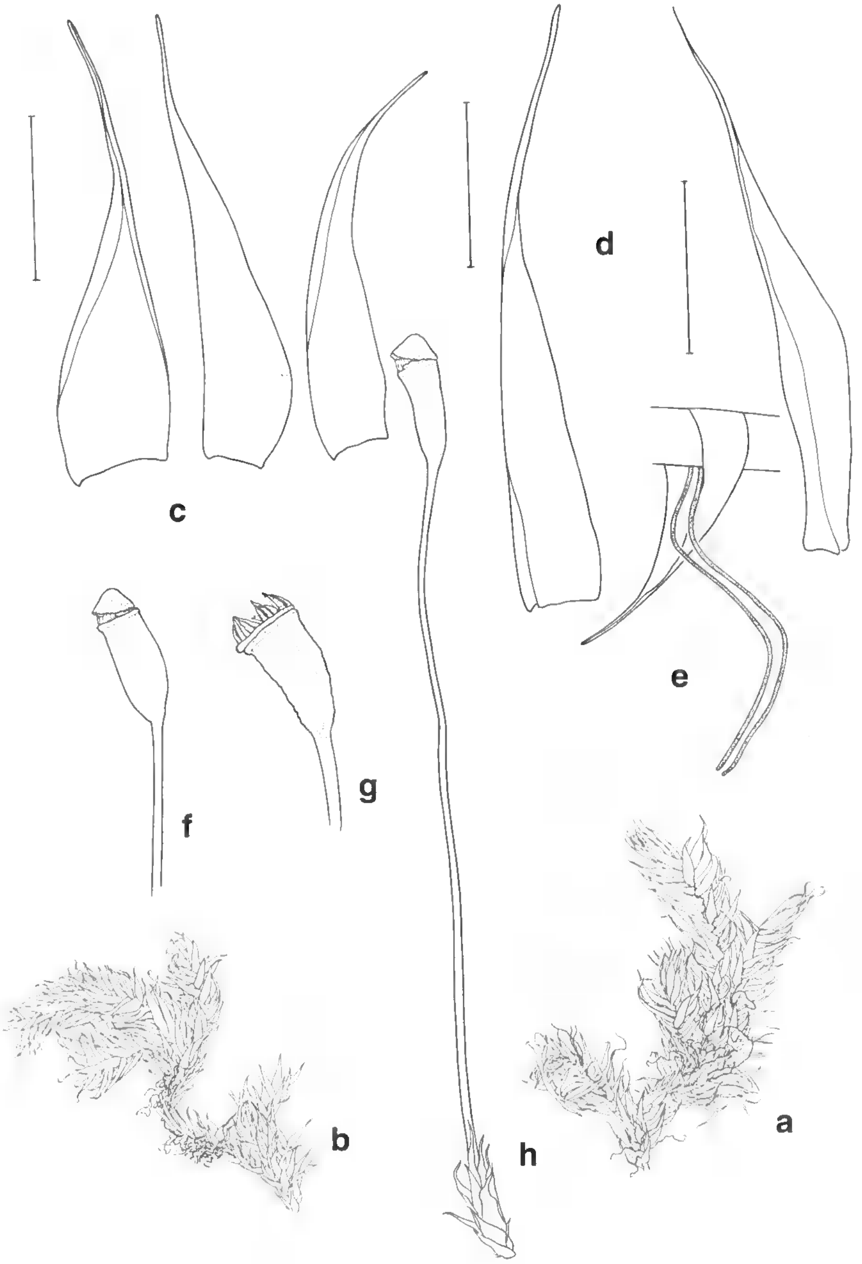

Fig. 3. Drawings of type specimens. **a,** habit of isotype of *Hypnum terrae-novae* var. *australe* (NY); **b,** habit of holotype of *Isopterygium acuminatum* (HO); **c,** branch leaves of *H. terrae-novae* var. *australe*; **d,** branch leaves of *I. acuminatum;* **e,** stem, leaf and axillary rhizoids; **f,** capsule with operculum of *H. terrae-novae* var. *australe;* **g,** capsule showing peristome of *H. terrae-novae* var. *australe* ; **h,** sporophyte showing perichaetial leaves and capsule of isotype of *I. limatum* (NY). (a, b, f, g, h drawn by C. Wardrop, c, d, e by H. Ramsay). Scale bars: 0.5 mm for leaves, 1mm for other drawings.

Beilschmiedia tawa, Carpodetus serratus, Melicytus macrophyllus and Myrsine australis. It is apparently more common on the South Island than the North Island and ranges from near sea level to c. 1650 m (but is common below c. 700 m only from Canterbury southward). Figs 5, 6.

In Scott and Stone (1976), Lewinsky suggested that *Isopterygium acuminatum* from Tasmania was merely a growth form of *Isopterygium limatum.* We have examined type material (Ramsay & Seur 1994) of *I. acuminatum* as well as many Tasmanian collections and we concur with Lewinsky's suggestion.

Fig. 4. *Austrohondaella limata* showing rhizoids in axil of lower stem leaf. (from *R.D. Seppelt 12897* in NICH; photograph by Z. Iwatsuki).

Fig 5. Australian distribution of *Austrohondaella limata.*

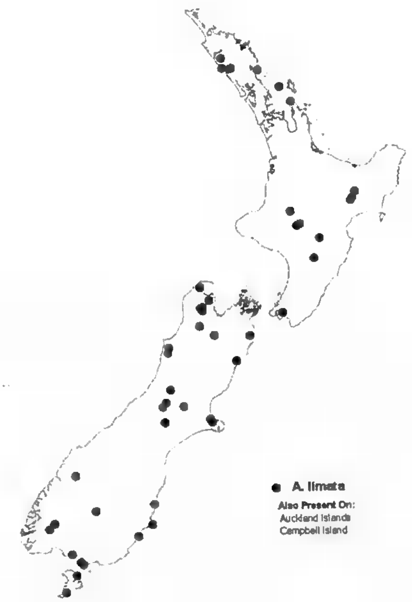

Fig. 6. New Zealand distribution of *Austrohondaella limata.*

Selected Specimens: Australia. New South Wales: Yarrangobilly Caves, *W.W. Watts 8822, 8823, 8807* (NSW). **Victoria:** Sabine Falls track, Angahook-Lorne state forest, 19 km NE of Apollo Bay, *H. Streimann 58986* (NICH, CANB); Bulga National Park, Lyrebird-Ash Tracks, *H. Streimann 51621* (NICH, CANB); Mt Cole State Forest, 27 km E of Ararat, *H. Streimann 54841* (CANB); Maits Rest, Ocean Road 10 km W of Apollo Bay, *H. Streimann 58644* (CANB). **Tasmania:** Williamsford - Montezuma Falls Track, *H. Streimann 59570A* (NICH, CANB, HO); North Dundas, *W.A. Weymouth 3037* (HO); Mt Rumney, *R.A. Bastow 199* (HO); Western Tiers, northern side of Projection Bluff, *R.D. Seppelt 12897* (NICH, HO); Lake Dobson Rd, Mt Field NP, *D.H. Vitt 29139 & H.P. Ramsay,* (CANB, HO); Pipelma track, Mt Wellington, *A.V. Ratkowsky H292* (CANB, HO); Roger River 6 km SW of Trowatta, *A. Moscal 10572* (CANB, HO). **Macquarie Island:** Green Gorge, *R.D. Seppelt 14306* (NICH, CHR 413613); Prion Lake, *R.D. Seppelt 011342* (NICH); Douglas Point, *R.D. Seppelt 12445* (NICH).

New Zealand: North Island: Maunganui Bluff, *A.J. Fife 10705* (CHR 570024); Coromandel Peninsula, Moehau, *L.B. Moore 254* (CHR 593700A, WELT M15107); Gisborne, Lake Waikaremoana, Panekiri Range, *G.O.K. Sainsbury s.n.*, 3 Mar 1940, (WELT M015126); Central Volcanic Plateau, Mt. Hauhungatahi, *J.K. Bartlett A11* (NICH); Tongariro National Park, southwest flank of Mt. Ruapehu, Blyth Hut track, *A.J. Fife 9803* (CHR 512033); NW Ruahine Range, Ohutu Ridge, *B.H. Macmillan 92/8* (CHR 482367). **South Island:** Mt. Burnett, near Collingwood, *A.J. Fife 11734* (CHR 581481); N.W. Nelson, Cobb Valley, *J.K. Bartlett A7* (NICH); N.W. Nelson, Arthur Range, Mt. Hoary Head, *J.K. Bartlett 19388* (NICH); Gouland Downs, Big River, *M.J.A. Simpson 7278* (CHR 106958); Mt Owen, Sanctuary Basin, *A.J. Fife 5061* (CHR 103645); Marlborough, Woodside Creek, *W. Martin 593* (CHR 587227); Canterbury, Arthurs Pass National Park, Bealey River Gorge, *V.O. Heinz 96/29 & B.H. Macmillan* (CHR 510127, NICH); Joyces Creek, tributary of Waimakariri River, *B.H. Macmillan 75/143* (CHR 264840); Westland, Kelly's Hill (=Kelly Range), *S. Berggren 2805* (NICH, WELT M1050); Otago, Otago

Peninsula, near Larnach's [Castle], *J. Child 6212* (CHR 429281, NICH); Dunedin, Tysons Wall, Leith Valley, *J. Child s.n.* (NICH 300228); Dunedin area, Swampy Summit, *W.B. Schofield 49995* (NICH); Akatore Stream, south of Dunedin, *K.W. Allison 1414* (CHR 577752); Tautuku Bay, Lake Wilkie, *W.B. Schofield 49432* (NICH); Southland, Garvie Mountains, above Lake Scott, *D. Glenny 6393* (CHR 509918); Bluff-Invercargill - Winton, *S. Berggren s.n.*, 1874 (NICH 278551). **Stewart Island.** Port Pegasus, *W. Martin 275.3* (CHR 577758); summit of Tin Range, *W. Martin 275.20* (CHR 593701). **Auckland Islands.** Auckland Island, Hanfield Inlet, *D.H. Vitt 10176* (CHR 448072). **Campbell Island.** Perseverance Harbour, *D.H. Vitt 2945* (CHR 577763).

Acknowledgments

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Telopea 12(3) 371–384

The genera *Isopterygium* Mitt. (*Bryopsida*, Hypnaceae) and *Isopterygiopsis* (Hedw.) Z.Iwats. (*Bryopsida*, Plagiotheciaceae) in Australia

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Abstract

A revision of the genus *Isopterygium* in Australia has resulted in recognition of only one species, *I. albescens* in Australia. Of the other species listed for the genus in this country, *Isopterygium minutirameum*, *I. novae-valesiae* and a number of other recorded names have been placed into synonymy with *I. albescens. Isopterygium arachnoideum* and *I. subarachnoideum* have been transferred to *Isopterygiopsis pulchella.* The presence of *Isopterygiopsis pulchella* (Schimp.) Z.Iwats. in Australia (considered doubtful by Streimann & Klazenga 2002) is confirmed and the types for Australian species of *Isopterygium arachnoideum*, and *I. subarachnoideum* are placed into synonymy with it. *Isopterygium albescens* is considered to be a member of the family Hypnaceae while *Isopterygiopsis pulchella* is in the Plagiotheciaceae.

Pseudotaxiphyllum pohliicarpum (Hypnaceae) is recorded as a new species for Australia.

Introduction

Prior to Iwatzuki's studies (1970, 1987), the genus *Isopterygium* contained more species, was very heterogeneous and had been placed variously in the Hypnaceae or Plagiotheciaceae. Iwatsuki transferred various species into a number of new genera, e.g., *Pseudotaxiphyllum*, *Isopterygiopsis*, *Herzogiella*, and *Taxiphyllum*, most of which are now included in the family Hypnaceae. The diagnostic characters for these new genera are based on morphological criteria such as absence of pseudoparaphyllia, the location and surface of rhizoids, size and wall of epidermal and cortical stem cells, type of propagules and presence or absence of an annulus (see Iwatsuki 1970: table 3, p. 339; Iwatsuki 1987: fig 1, p. 446 & table 1, p. 450).

Isopterygium was included in the new family Pylasiadelphaceae created by a division of Sematophyllaceae s. l. by Goffinet and Buck (2004) in their recent interpretation of moss classification. As *Isopterygium* does not have a number of the characters that define the Pylasiadelphaceae, e.g., the alar cells enlarged and coloured and rostrate operculum, we do not agree with this placement and have returned *Isopterygium* to the family Hypnaceae.

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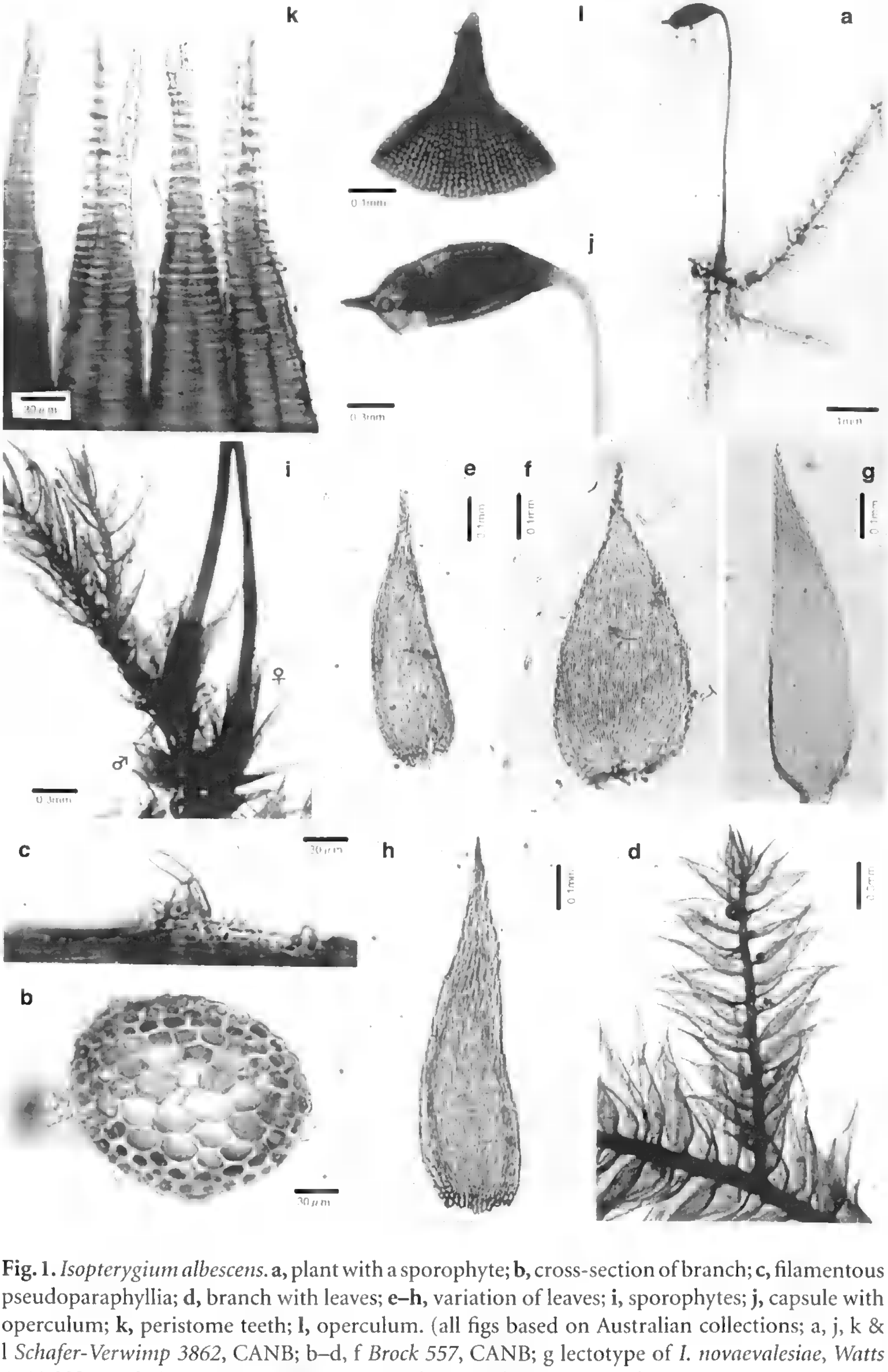

Fig. 1. *Isopterygium albescens.* **a,** plant with a sporophyte; **b,** cross-section of branch; **c,** filamentous pseudoparaphyllia; **d,** branch with leaves; **e–h,** variation of leaves; **i,** sporophytes; **j,** capsule with operculum; **k,** peristome teeth; **l,** operculum. (all figs based on Australian collections; a, j, k & l *Schafer-Verwimp 3862*, CANB; b–d, f *Brock 557*, CANB; g lectotype of *I. novaevalesiae*, *Watts 1902*, NSW; e, h, j *Streimann 45351*, CANB; photographs by Z. Iwatsuki).

The genus *Isopterygium* contains more than 200 taxa of which 11 names are recorded for Australia, including five endemics (Streimann & Klazenga 2002). Present studies have reduced the total species number in Australia for *Isopterygium* to one, and two of the previously listed endemic species known from types or only a few collections, have been determined as *Isopterygiopsis pulchella.*

The other recorded species, *Isopterygium limatum*, found in New Zealand (Fife 1985) and Australia (Streimann & Klazenga 2002), has been under investigation since it lacks the rostrate operculum, has a well-differentiated annulus, different pseudoparaphyllia, as well as characters such as axillary papillose rhizoids that are not present in *Isopterygium.* Based on studies of Australian, New Zealand and subantarctic (including Macquarie Island, Seppelt 2004) material, this taxon has been placed in a new genus *Austrohondaella* (Iwatsuki et al. 2009), which has been placed in the Hypnaceae. *Isopterygium acuminatum* and *I. amblyocarpum* are considered synonymous with it.

Isopterygium

Isopterygium Mitt., *J. Linn. Soc. Bot.* 12: 21 (1869).

Lectotype: *Hypnum tenerum* Sw. = *Isopterygium tenerum* (Sw.) Mitt. selected by Z. Iwatsuki & M. Crosby, *J. Hattori Bot. Lab.* 45: 389–393 (1979).

Etymology: from the Greek *isos* (equal), *pteryx* (wing like) and *ion* (diminutive suffix) in reference to the delicate wing like leaf arrangement.

Defining characters for the identification of *Isopterygium* (Iwatsuki 1987) include leaves ovate to ovate-lanceolate; leaf apices more or less serrulate; costa short and double or absent; rhizoids smooth, rarely scabrous, originating below and between leaf insertions not in leaf axils; epidermis of normal small cells, outer cortical stem cells small and thick-walled forming a sclerodermis, central strand lacking; propagules when present, filamentous or short; sporophytes almost uniform being hypnaceous (diplolepidous) but with absence of annulus, with non-collenchymatous exothecial cells and a short rostrate operculum Several filamentous pseudoparaphyllia are usually seen around a branch primordium in *Isopterygium.* When a branch primordium grows into a branch a few more or less triangular leaves develop first, occurring at the base of young branches, and primordia are also present on the main stems surrounding the triangular leaves.

Chromosome numbers, summarised here and obtained from Fritsch (1991) and Goldblatt and Johnson (1994, 1998, 2003) are available for several species of *Isopterygium* (North America, n = 11, 22, 12 (11+ m); Europe, n=12 (11+m),; Japan, n=11,12 ; India, n=11 (10+m), 12, 22, but none is available for Australian populations.

Isopterygium albescens (Hook.) A.Jaeger, *Ber. Thatigk. St. Gallischen Narwiss.* Ges. 1876–77: 433 (1878). *Hypnum albescens* Hook. in Schwägr., *Sp. Musc. Suppl.* 3(1): 226b,Tab. CCXXV1. b (1828).

Type: In regno Nepal Indiae lectum dedit Pr. Hooker.

Isopterygium latifolium Broth., *Oefv. Finsk. Vetensk. Soc.* 42:114 (1900), *syn. nov.* Type: Australia, New South Wales: Alstonville Road, Ballina, *W.W. Watts 211,* holotype: NSW; isotype: H-BR, MEL 59608).

Isopterygium howeanum Broth. & Watts, *Proc. Linn. Soc. New South Wales* 40: 380–381 (1915) , *syn. nov.* Type: Hillside, back of Johnsons, Lord Howe Island. *W.W. Watts 112,* 8.vii.1911 holotype: (NSW); isotype: (H-BR).

Hypnum candidum Müll.Hal., Linnaea 35: 624 (1868) , *syn. nov.* Type: Australia, New South Wales, Ash Island, Hunter River, *Mrs E. Ford* (MEL 59547). *Isopterygium candidum* (Müll.Hal.) A.Jaeger, *Ber. Thätigk. St. Gallischen Naturwiss. Ges.* 1876–77: 437 (1878) (Gen. Sp. Musc. 2:4503), fide J. H. Willis, *Victorian Naturalist* 71: 161 (1955).

Hypnum molliculum Sull., *Proc. American Academy of Arts and Sciences* 3:78 (1854). Type: Hawaii, Mauna Kea, *Wilkes* (BM). *Isopterygium molliculum* (Sull.) Mitt. in Seem., Fl. Vit. 399 (1873), fide Dixon *Proc. Linn. Soc. New South Wales* 55: 295 (1930).

Isopterygium sublatifolium Broth., *Proc. Linn. Soc. New South Wales* 43: 564 (1918), *nom. nud. in synon.*

Hypnum minutirameum Müll.Hal., *Syn. Musc. Frond.* 2: 689 (1851); *Bryol. Jav.* II, p. 191, Tab. 290 (1808), *syn. nov.* Type: Java: Blume, in Herb. Al. Braun, *syn. nov Isopterygium minutirameum* (Müll.Hal.) A.Jaeger, *Ber. Thätigk. St. Gallischen Naturwiss. Ges.* 1876–77: 434 (1878). *Taxiphyllum minutirameum* (Müll.Hal.) H.A.Mill. & D.R.Smith, *Micronesica* 4: 225 (1968).

Hypnum norfolkianum Müll.Hal., *Linnaea* 37: 160 (1872). Type: Norfolk Insula. Ferd. Muller mixed with *Rhacopilum convolutaceum.* holo: BM (Hampe); isotype: NY. *Isopterygium norfolkianum* (Müll.Hal.) A.Jaeger, *Ber. Thätigk. St. Gallischen Naturwiss. Ges.* 1876–77: 435 (1878), *fide* Streimann (2002), p.100–101.

Isopterygium baileyanum Müll. Hal. *ex* F.M. Bailey, *Syn. Queensland Fl.* Suppl. 2: 71 (1888). *nom. nud. in synon.* Based on: Qld: Kedron Brook and Port Curtis *F.M. Bailey* (BRI).

Isopterygium amoenum Broth., *Oefvers. Finska Vetensk. Soc. Foerh* 42: 112 (1900), *syn. nov.* Type: Australia, New South Wales: Richmond River, *W.W. Watts, n. 802, 888,* lectotype: HBR (*Watts 888*), isolectotype: NSW (*Watts 888*) [selected here]; syn: H-BR(*Watts 802),* isosyntypes: MEL, NSW (*Watts 802*).

Isopterygium neocaledonicum Thér., *Bull. Acad. Int. Géogr. Bot.* 19: 23 (1909), *syn. nov.* Type: New Caledonia, Rivière Carricouyé, *Franc* (BM).

Isopterygium viridepallens Müll.Hal. *ex* Burges, *Proc. Linn. Soc. New South Wales,* 60: 93 (1935). *nom. nud. in synon.* Based on: N.S.W. Gosford *W. Forsyth 442,* 19.ix.1891; Lane Cove *W. Forsyth 497,* National Park *W. Forsyth 492* (NSW).

Isopterygium minutirameum f. *brevifolium* M.Fleisch. *Die Musci der Flora von Buitenzorg* 4: 1427. 1923. *Taxiphyllum minutirameum* (Müll.Hal.) H.A.Mill. & D.R.Smith var. *brevifolium* (M.Fleisch.) H. Whittier, *Florida Scientist* 38: 103 (1975).

Hypnum austropusillum Müll.Hal., *Linnaea* 37: 159 (1872). Type: Qld: Brisbane River, *Dietrich.* (BRI). *Isopterygium austropusillum* (Müll.Hal.) A.Jaeger, *Ber. Thätigk. St. Gallischen Naturwiss. Ges.* 1876–77: 435 (1878). (Gen. Sp. Musc. 2: 501).

Isopterygium austrosubulatum Müll.Hal. *ex* Burges, *Proc. Linn. Soc. New South Wales* 60: 93 (1935), *nom. nud. in synon.* A Watts specimen bearing this name is held at NY (W. Buck, pers. comm.): *W.W. Watts 1586,* Sep 1897 (*n.v.*).

Isopterygium novae-valesiae Broth., *Oefv. Finska Vet. Soc. Foerh.* 42: 113 (1900), *syn. nov.* Type: Australia, New South Wales : Richmond River, Fernleigh, *W.W. Watts 1902*, lectotype [selected here]: H-Br, isolectotype: NSW. From the original list of types the following become *residual syntypes* -. New South Wales, Richmond River, Fernleigh, *W.W. Watts* (n. *1384, 1399, 1403, 1900*); Pearces Creek (*1395, 1408*); Teven (*1430* ex. p.) Alstonville (*470*); Uralba (*1801*), all held H-BR, NSW, except for *Watts 1395* (which at NSW is a poor specimen, not *Isopterygium*).

Illustrations: Dozy & Molkenboer, *Bryologia Javanica*, vol II, p. 193, tab. CCXC, (1868), as *Hypnum*; Bartram, *Mosses of the Philippines*, plate 27, fig. 474 (1939). Gangulee, *Mosses of Eastern India and Adjacent Regions* 7: 1960, fig 1007 (1979). Noguchi, *Illustrated Moss Flora of Japan* 5: 1051, fig. 462A (1994).

Plants autoicous, slender, small to medium-sized, in pale yellow-green, grey-green to green, slightly glossy prostrate mats. Stems creeping, irregularly pinnately branched, to 6.0 cm long. In cross-section, stem without central stand, and the cortex with 2 outer layers of firm-walled cells. Pseudoparaphyllia filamentous. Branches short, ascending, often loosely foliated. Rhizoids smooth, red, sparsely developed on underside of stem between leaves. Branches suberect, simple or with branchlets 1.0–1.5 cm. Leaves ovate,

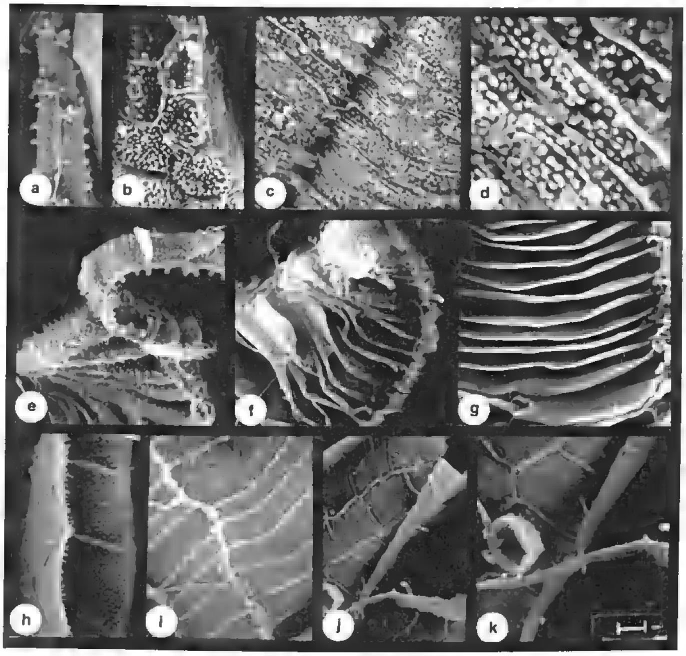

Fig. 2. Scanning electron micrographs of the peristome of *Isopterygium albescens (as I. novaevalesiae.* **a**, close view of apex of exostome tooth; **b**, tooth below apex showing papillose surface; **c & d**, pattern of lamellae and papillae between, on abaxial surface in lower part of tooth; **e**, side view of exostome tooth near apex curled over showing lamellae; **f**, closer view of lamellae in base of mid tooth; **g**, lamellae towards base of tooth, smooth no papillae; **h**, abaxial view of endostome segment near apex; **i**, abaxial view of basal membrane with smooth surface; **j**, cilia curved back over basal membrane; **k**, spore, cilium and basal membrane behind. [*H.P. Ramsay 181115* (NSW).] Scale bar a, b, e, g, h, k = 20 µm; c, f, i = 10 µm; j = 100 µm.[SEM's prepared by Meera Jayachandran at University of New South Wales.]

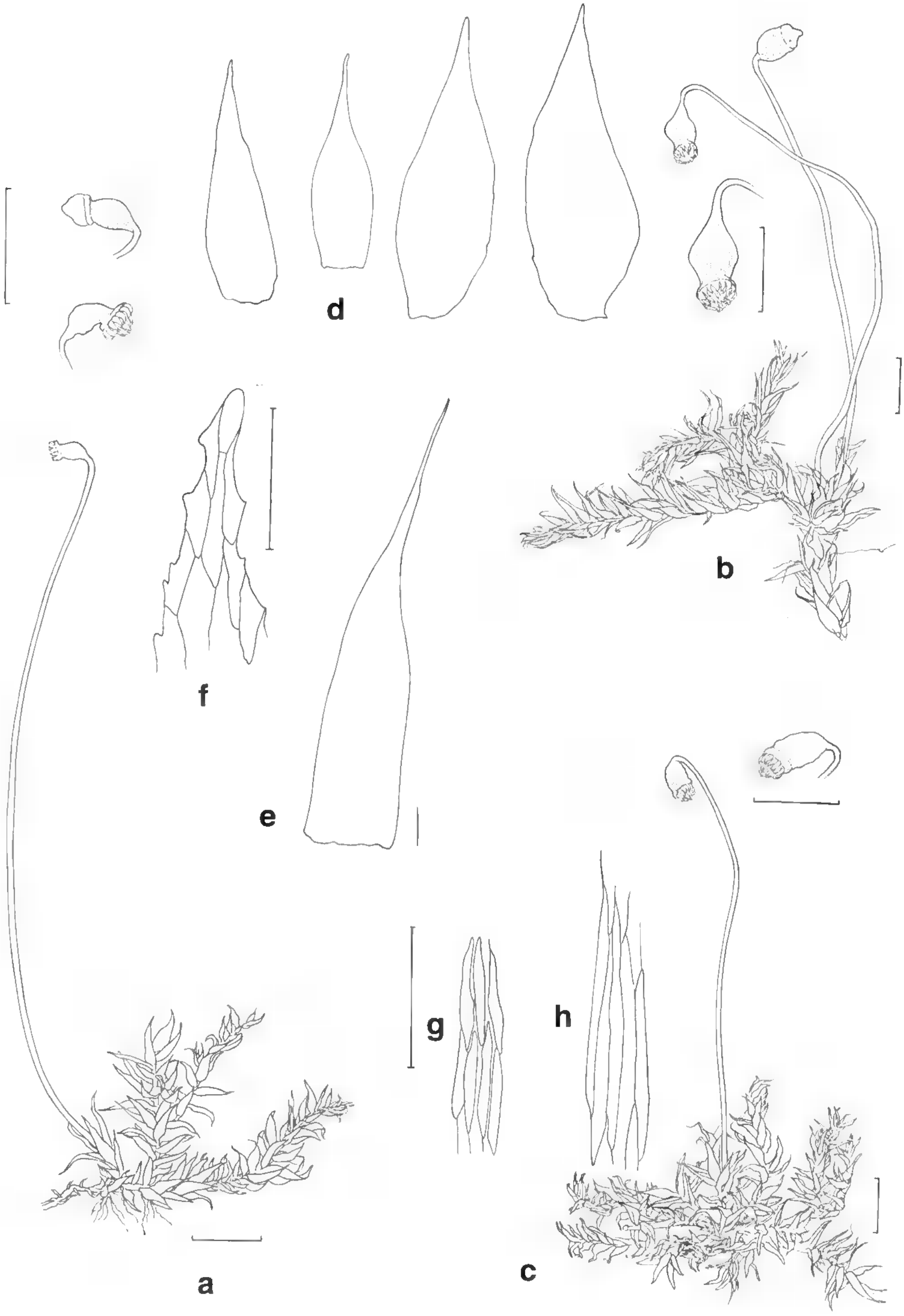

Fig. 3. Illustrations showing variation in *Isopterygium albescens* in Australia. **a,** habit with capsules (as *Isopterygium novaevalesiae*, isolectotype, *Watts 1902*, NSW); **b,** habit with capsules (as *Isopterygium minutirameum*, *Watts 4584*, NSW); **c,** habit with capsules (as *Isopterygium albescens, Watts 235*, NSW); **d1–4,** variation in leaves: **d1** stem leaf, **d2–d4** branch leaves; **e,** perichaetial leaf; **f,** apical leaf cells; **g,** upper leaf cells; **h,** midleaf cells. (Drawings by: D. Mackay (habit of *I. novaevalesiae*), C. Wardrop & H.P. Ramsay). Scale bars: 1.0 mm for habits and leaves; 100 μm for cellular drawings.

ovate-lanceolate or lanceolate, usually slightly concave, erect-patent, 0.6–1.2 × 0.28–0.35 mm, asymmetrical, margins entire or obscurely serrate or denticulate above, apex gradually acuminate to a slenderly tapering narrow acumen, slightly falcate towards ends of branches. Laminal cells in midleaf narrow, 70–100 × 4–8 μm, linear to vermicular; apical cells short rhomboid (4:1); cells in alar region consisting of 2–3 small thick walled, shortly rectangular or irregularly shaped hyaline cells, basal row of subrectangular cells. Perigonia on branches and lower parts of stems, rounded budlike. Perichaetia on stems, inner perichaetial leaves gradually long acuminate. Calyptra smooth, cucullate 1.0 mm long. Seta long-exserted, 0.6–1.2 cm, pale red; capsules frequently produced, oblong-ovoid, curved, horizontal or pendulous, operculum bluntly curved-rostrate; peristome double, exostome teeth 16, endostome 16, same length as exostome, with single cilium as long as segments. Spores 9–13 μm, finely papillose. Figs. 1–4

Distributed in Himalayas, Malesia, and tropical and subtropical Asia as far north as Japan, on Pacific Islands, in New Zealand and Australia. Specimens collected by W.W. Watts on Lord Howe Island as *Isopterygium howeanum* or *I. candidum* are *I. albescens.* With the transfer to *Isopterygiopsis* of *Isopterygium pulchellum* and the exclusion of *I. limatum* from the genus (Iwatsuki et al. 2009), distribution of *Isopterygium* in Australia is confined to the mainland chiefly in coastal regions from tropical northern Western Australia, Northern Territory and Queensland south to New South Wales and Victoria.

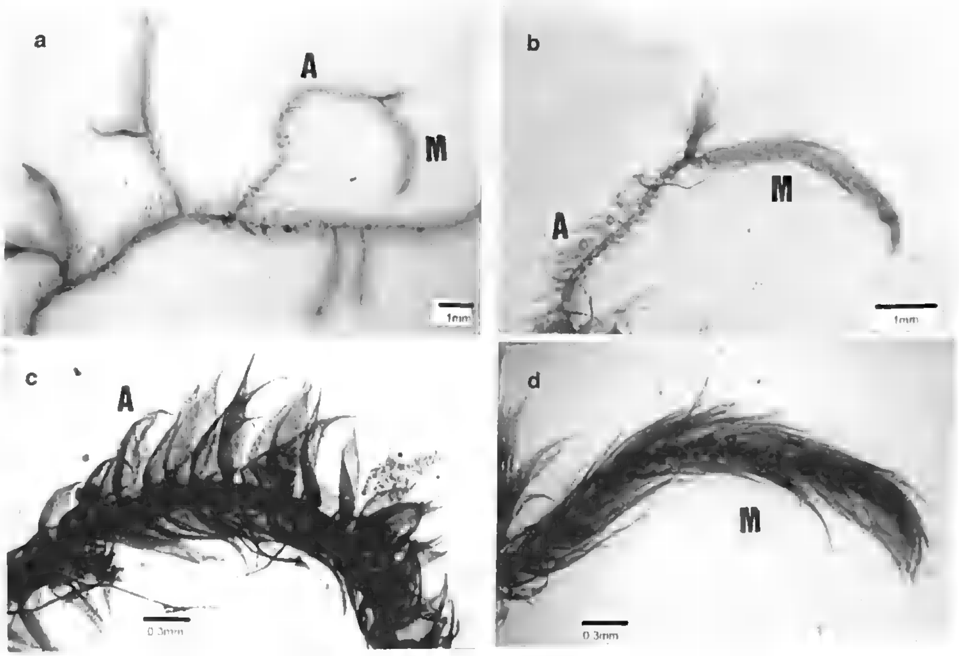

Fig. 4. *Isopterygium albescens*, showing variation of leaves. **a, b,** part of plant showing two types of leaves (A shows ovate to ovate-lanceolate leaves, M shows lanceolate leaves); **c,** part of branch with ovate to ovate-lanceolate leaves (plants with this type of leaves have been called *Isopterygium albescens*); **d,** branch with lanceolate leaves (plants with this type leaves have been called *Isopterygium minutirameum*). (all from *Russell-Smith 6200,* CANB; photographs by Z. Iwatsuki).

Dalton et. al. (1991) noted that *I. albescens* had been listed for Tasmania although Scott and Stone (1976) recorded it only from the mainland. Streimann and Klazenga (2002) have listed *I. albescens* for Tasmania but no specimens have been located by us. The genus is thus absent from the temperate regions of southern Western Australia, South Australia and Tasmania. Fig. 5

Selected specimens. Western Australia: Galvin Gorge, *G. Kantak & S.P. Churchill 687* (NY, NSW); **Northern Territory:** Kakadu, *L.A. Craven & G. Whitbread 6801* (CANB); Wangi Road, Walker Creek 68 km SSW of Darwin, *H. Streimann 8814* (CANB); Katherine Gorge, *G.E. Kantak* 696 (CANB). **Queensland:** Babinda, *W.W. Watts Q300* (NSW); Malanda, *W.W. Watts 577* (NSW); Cairns, *W.W. Watts 235* (NSW). **New South Wales:** Manning River, *E. Cheel 485* (NSW); Pimlico, Richmond River, *W.W. Watts 432* (NSW); Alstonville Road, Alstonville, *W.W. Watts 612* (NSW); Wardell Road, Richmond River, *W.W. Watts 687* (NSW); Stanwell Park, *W.W. Watts 8267* (NSW); Lord Howe Island, north end of island in closed rainforest, *D.H. Vitt 28327* (NSW). **Victoria:** Dandenongs, East Gippsland, *E. Ronfield s.n.* (MEL).

We had much difficulty in identifying and separating specimens of *I. albescens* and *I. minutirameum*, because these two species are extremely variable in shape and colour of leaves. *Isopterygium albescens* and *I. minutirameum* are usually distinguished as follows:

1. Plants often whitish, leaves ovate to ovate-oblong .... ***I. albescens***
1. Plants not whitish, leaves lanceolate, slenderly tapering to a narrow acumen .... ***I. minutirameum***

However, the above key does not work well for many specimens of *Isopterygium* in Asia or Australia. Recently, we found a very interesting specimen which has two types of leaves on one plant. The specimen had been determined as *I. minutirameum* (Northern Territory, Butterfly Springs, *J. Russell-Smith 6200*, CANB). As shown in Fig. 4 some branches (marked by M) have leaves defined in the key as *I. minutirameum*, and some other branches (marked by A) have leaves defined in the key as *I. albescens*. Identifications of specimens of *I. albescens* and *I. minutirameum* have often been changed from *I. albescens* to *I. minutirameum* or vice versa. For these reasons, we reduce *I. minutirameum* to a synonym of *I. albescens*. In North America, *Isopterygium tenerum*, which is related to our *I. albescens*, is also extremely variable and includes two types of leaves comparable to those of *I. albescens* and *I minutirameum*. These variants

Fig. 5. a, Distribution of *Isopterygium albescens* in Australia; **b,** Distribution of *Isopterygiopsis pulchellum* in Australia.

have been given varietal status, e.g. var. *fulvum*, var. *minus*, var. *groutii*, etc. but Crum and Anderson (1981) note that the species is extremely variable, and that it is useless to segregate such varieties.

There has been confusion in the identity of the species *Isopterygium novae-valesiae* Broth., considered an Australian endemic until these studies, as it has been known as either *Isopterygium* (Broth. 1900) or *Taxithelium* (Broth. 1908). While revising the Australian species of *Taxithelium*, the type collections from H-BR and isotypes from NSW of *Isopterygium* [*Taxithelium*] *novae-valesiae* were examined by Ramsay et al. (2002a) and again recently by Paulo Câmara at the Missouri Botanical Garden, who has been carrying out a world revision of the genus *Taxithelium*. Both confirm that the type specimens listed by W.W. Watts and held at H-BR and NSW do not contain any *Taxithelium* species. *Isopterygium novae-valesiae* has non-papillose cells while *Taxithelium* has pluripapillose cells. Brotherus, however, did allow for non-papillose species in his concept of *Taxithelium*, a view not currently accepted.

The lectotype specimen (*Watts 1902*) of *Isopterygium novae-valesiae* has non-papillose cells, and after careful examination, we have reduced it to synonymy with *I. albescens*. Specimens of this vary somewhat from other collections of *I. albescens* as recognised here. They are often pale yellow-green and have much longer setae and slightly larger more acuminate leaves than the general collection.

Many specimens from north-eastern New South Wales were examined and identified by Brotherus as *Isopterygium candidum* (Müll.Hal.) A.Jaeger in the 1890's. Most of the specimens from New South Wales with this name have been re-determined as *I. minutirameum* (now *I. albescens*). However, those from Lord Howe Island are correctly named as *I. albescens*.

Isoptergiopsis

Isopterygiopsis (Hedw.) Z.Iwats., *J. Hattori Bot. Lab.* 33: 379–380 (1970)

Type: *Plagiothecium muellerianum* Schimp.

Etymology: derived from the name *Isopterygium* (see above) and the Greek *-opsis* (appearance)in reference to the similarity between the two genera.

Plants dioicous or autoicous, medium sized to small, shiny; stems creeping, irregularly pinnately branched; in cross section of stem, epidermal cells large, thin-walled and often hyaline, or small and more or less thick-walled; central strand indistinct,. rhizoids papillose and axillary; pseudoparaphyllia absent; when present, gemmae occur as axillary fascicles of filamentous propagulae 3–7 cells long; annulus differentiated. Leaves erect to wide-spreading and weakly to distinctly complanate; narrowly lanceolate triangular, acuminate, entire. Setae long, capsules suberect, annulus 2 rows of cells, operculum bluntly low-conic. Peristome hypnoid.

Isopterygiopsis was described by Iwatsuki (1970) for species similar in appearance to *Isopterygium* in size, but different in having no pseudoparaphyllia on stems, large hyaline or thin-walled epidermal cells in stem cross-sections and axillary papillose rhizoids instead of smooth rhizoids arising below leaf insertion, filamentous propagules and having a differentiated annulus. It is more similar to *Plagiothecium* in characters of pseudoparaphyllia and propagulae, but differs in having non-decurrent leaf-bases

(Iwatsuki 1987). As part of a revision of the genus *Isopterygium* for the Flora of Australia by us, the specimens for *Isopterygium pulchellum* (Hedw.) A.Jaeger = *Isopterygiopsis pulchella* (Hedw.) Iwats. were examined as its occurrence in Australia has been reported as doubtful' (Streimann & Klazenga 2002). Recent studies of specimens and types of *Isopterygium arachnoideum* and *I. subarachnoideum,* now placed into synonymy with *Isopterygiopsis pulchella* (see below), confirm its presence in Australia.

Isopterygiopsis pulchella (Hedw.) Z.Iwats., *J. Hattori Bot. Lab.* 63: 450 (1987). *Leskea pulchella* Hedw., Sp. Musc. 220 (1801). *Isopterygium pulchellum* (Hedw.) A.Jaeger & Sauerb., Ber. St. Gall. Naturw. Ges. 1876–77: 441 (1878).

Type: In silvis umbrosis Scotiae (Hedwig 1801).

Isopterygium arachnoideum Broth., *Oefvers Finska Vetensk.-Soc. Foerh.* 42: 112 (1900). Type: Australia, New South Wales, Richmond River, Teukombil (=Tuckumbil) Hunter's Scrub, on tree fern trunks. *W.W. Watts 549,* lectotype H-BR, isolectotype (4 specimens in NSW)[selected here]. syntype: Three mile scrub, tree fern trunks *W.W. Watts 879* (NSW, H-BR). [Note *W.W. Watts 587* in MEL is not a type, refer to Ramsay and Seur (1994)]

Isopterygium subarachnoideum Broth. *Oefvers Finska Vetensk.-Soc. Foerh* 42: 113 (1900). Type: Australia, New South Wales, Richmond River, Hunter's Scrub, on tree fern trunk, *W.W. Watts 744,* lectotype: H-BR; isolectotype: NSW [selected here]. No specimen of the syntype *Watts 588* was found in H-BR or NSW.

Illustrations: Crum and Anderson, *Mosses of eastern North America,* vol. 2, fig 582 (1981); Ignatov & Ignatov, *Moss flora of the middle European Russia,* vol. 2: fig 439 (2004); Ireland, *Moss flora of the Maritime Provinces*: fig. 357 (1982); Nyholm, *Illustrated moss flora of Fennoscandia.* II. Musci, fasc. 5: fig. 411 (1965) - all as *Isopterygium pulchellum.* Smith, *The moss flora of Britain and Ireland,* 2nd ed.: fig. 295. 9–11 (2004); Zhang & Si, Hypnaceae. *Moss flora of China,* English Version: pl. 689 (2005) - both as *Isopterygiopsis pulchellum.*

Plants autoicous, small and slender in shiny, bright-green or yellow to greyish-green flat mats. Stems creeping, mostly unbranched with several arising at base of perichaetia, stem in cross section with epidermal cells not so large, with outer wall thin or slightly thickened and with an indistinct central strand. Branches numerous, often ascending; pseudoparaphyllia absent. Leaves usually not crowded, erect to wide-spreading and weakly to distinctly complanate, often secund at tips, 0.7–1.2 mm long, narrowly lanceolate-triangular, slenderly acuminate, not decurrent, less than 0.2 mm wide at base, entire, ecostate. Laminal cells linear in midleaf 35–70 µm x 5 µm , 7–14:1 long as wide, cells scarcely differentiated at basal angles. Propagules occasionally present, axillary fusiform or cylindrical, 2–5 cells long. Perigonia numerous and usually present on lower stems. Perichaetia on stems. Perichaetial leaves erect, similar in size to leaves. Setae 8–16 mm long, orange or yellow, becoming orange-red; capsules suberect and nearly symmetric to inclined and asymmetric, oblong-cylindric, capsules mostly 1.0–1.5 mm., annulus of 2 rows of cells; operculum low-conical with a short rostrum; peristome hypnoid, endostome with non-perforate segments and single (sometimes paired) cilia. Spores 9–13 µm, minutely roughened. Chromosome numbers n=10+m, 10+2m, 22 (none Australian, Fritsch 1991). Fig. 6

Distributed, in North America, Europe, Asia, Africa, New Zealand and Australia (Queensland, New South Wales, Victoria, Tasmania). In N.S.W. most specimens occur

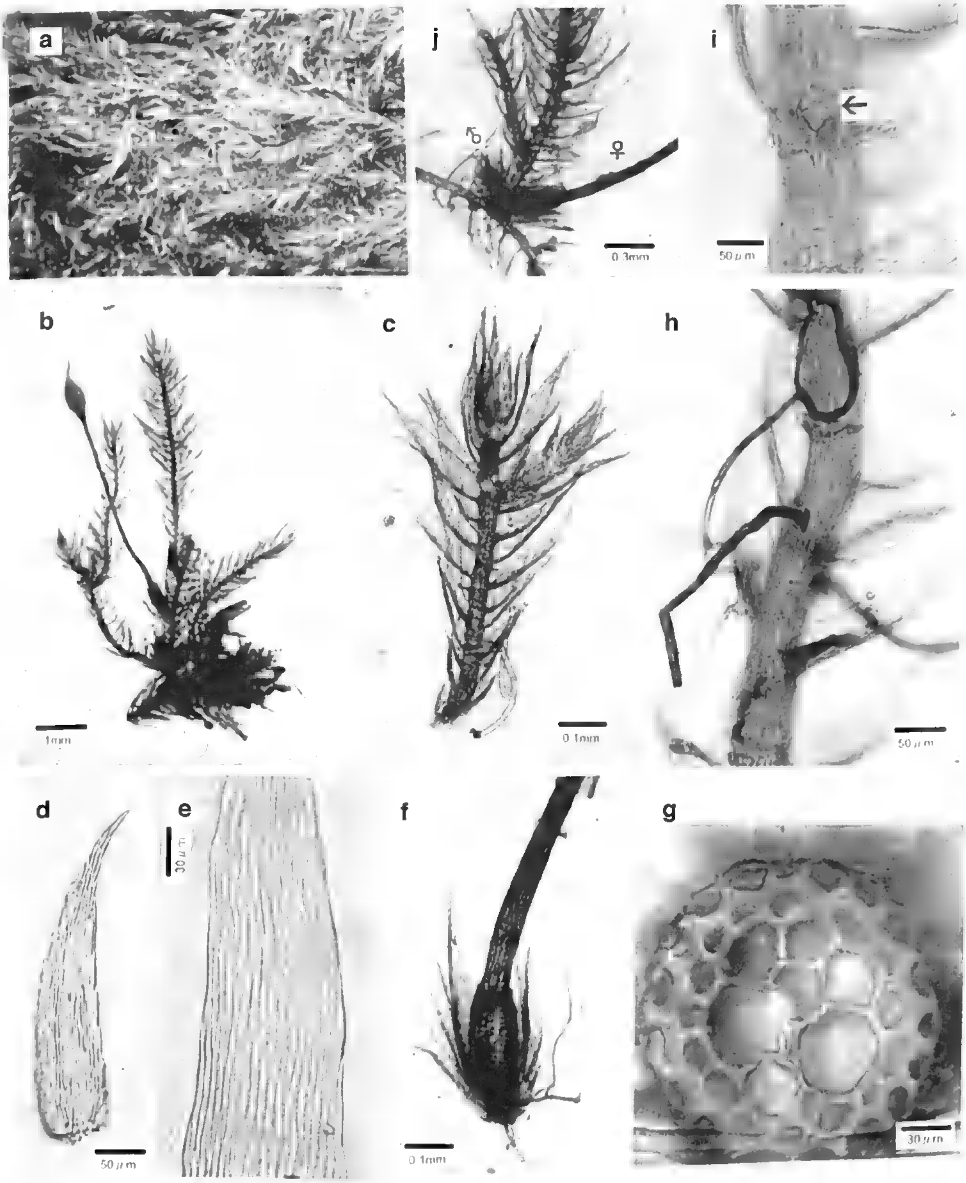

Fig. 6. *Isopterygiopsis pulchella.* **a,** plants; **b,** plant with sporophyte; **c,** branch; **d, e,** leaves; **f,** perichaetium; **g,** cross-section of stem; **h,** branch with rhizoids; **i,** branch with branch primordia (arrow); **j,** plant with male and female inflorescences. (all based on Australian material; a, c–e, & g–j *I.R. Telford*, CANB; b & f *W.W. Watts 577*, NSW; photographs by Z. Iwatsuki).

on the trunks of tree ferns from sea level to subalpine in the Blue Mts. and on the coast and coastal ranges as far north as the Richmond River district and the Border Ranges between N.S.W. and Qld possibly as far north as Eungella National Park. In Tasmania it occurs mainly on wood or tree trunks in the west and south-west at altitudes below 300 m. Fig. 5

Selected Specimens: Australia: Queensland: McPherson Range, Coomera Range, *I.R.Telford s.n.* (CANB). **New South Wales:** Valley of Waters, Blue Mts, *W.W. Watts 5434, 5435, 5436, 10471* (NSW); Woodford, Blue Mts, *W.W. Watts 8275* (NSW); Brunswick River, *W.W. Watts 1586, 1591*(NSW), *4195* (MEL); Tuckombil, *W.W. Watts 577 (as I. arachnoideum) 4912, 4913, 4908* (NSW), *W.W. Watts 587 (as I. arachnoideum)* (MEL); Ballina *W.W. Watts 2874, 5849* (NSW); Stanwell Park *W.W. Watts 8277* (NSW); Cambewarra *W.W. Watts 6590, 9930, 9946* (NSW); Bulgong Heights *W.W. Watts s.n.*, May 1916 (NSW 245517); Belmore Falls *W.W. Watts 9822* (NSW); Nowra *W.W. Watts 8268* (NSW); Tomerong *W.W. Watts 6235, 6236* (NSW); "Kingwell", Wyong *W.W. Watts 9604, 9480, 8971, 8972, 9631, 9715, 9532, 9722* (NSW); Gladesville, Sydney *W.W. Watts 9289* (NSW); Manly, Sydney *W.W. Watts 6815, 6820* (NSW), Neutral Bay, Sydney *W.W. Watts 8000* (NSW); Brindle Creek, Wiangarie S.F. *H. Streimann s.n.* (CANB); Dorrigo N.P. *H. Streimann s.n.* (CANB); **Victoria:** Mt Drummer, *N.A.S. Wakefield s.n.* (MEL 1031453); **Tasmania:** West Coast *W.A. Weymouth 2793* (HO); Zeehan Railway, *W.A. Weymouth 630* (HO); Recherche, *W.A. Weymouth 2586, 2587, 2618, 2619* (HO).

The following key is provided to assist in identifying the now recognised Australian taxa that were formerly *Isopterygium*, i.e. *Isopterygium, Isopterygiopsis* and *Austrohondaella.*

1. Leaves acuminate with more or less serrulate apices; rhizoids smooth, arising between leaves on stem; pseudoparaphyllia filamentous; capsule curved, horizontal or pendulous; annulus absent, operculum bluntly apiculate or curved rostrate .... ***Isopterygium albescens***

1. Leaves with entire apices; rhizoids papillose, arising from leaf axils; pseudoparaphyllia absent or foliose; capsule erect or suberect to inclined; annulus present; operculum low conic or blunt

    2. In section, stems with large thin-walled epidermal cells, thick-walled outer cortex, thin-walled inner cells, central strand present; capsule suberect to inclined, operculum low conic; pseudoparaphyllia absent .... ***Isopterygiopsis pulchella***

    2. In section, stem with small epidermal cells, an outer sclerodermis and inner thin walled cortical cells, central strand absent; capsule erect, symmetrical; operculum bluntly conic; pseudoparaphyllia foliose .... ***Austrohondaella limata***

New records for Australia

Among the Australian collections examined during this study, the following specimens of *Pseudotaxiphyllum pohliicarpum* (Hypnaceae) were discovered and are clearly identified by the *Pohlia*-like gemmae (Iwatsuki 1987, Noguchi 1994). The earliest collection is that of Watts in 1916, and a more recent collection is that of H. Streimann in 1991. These are the first records of this species for Australia.

Pseudotaxiphyllum pohliicarpum (Sull. & Lesq.) Z.Iwats., *J. Hattori Bot. Lab.* 63: 449 (1987). *Hypnum pohliaecarpum* Sull. & Lesq., Proc. Am. Ac. Art Sc. 4: 280 (1859). *Isopterygium pohliicarpum* (Sull. & Lesq.) A.Jaeger, *Ber. Thätigk. St. Gallischen Naturwiss. Ges.* 1876–77: 442 (1878).

Specimens examined: Australia: New South Wales: Northern Tablelands: Weeping Rocks, New England National Park, 72 km of Armidale, *Nothofagus–Elaeocarpus* dominated forest, at base of escarpment, on shaded rock face, *H. Streimann 47736* (CANB, NY). Central Coast: Sassafras Gully, Springwood W.W. Watts 10917 Jan 1916 (NSW 245625).

Distribution: Japan, China, Vietnam, Laos, Thailand, Philippines, new to Australia.

Names transferred elsewhere or specimens not found

Isopterygium caespitulosum Paris, *Index Bryol. Suppl.* 218 (1900), *nom. nud.* = *Taxicaulis caespitulosus* Müll.Hal., *nom. nud.* Not found.

Isopterygium nitens E.B.Bartram. A specimen labelled type ('co-type') with this name at NSW collected in Western Australia was redetermined by Bartram as *Sauloma zetterstedtii* (Müll.Hal.) A.Jaeger. Subsequently in a note J. H. Willis says he preferred to treat it as the 'western form of *Sauloma tenella* (Hook.f. & Wilson) Mitt.'

Isopterygium pseudosubulatum (Müll.Hal.) Paris, *Ind. Bryol. Suppl.* 220 (1900) (*Taxicaulis* 1887) is a non Australian taxon (see Streimann & Klazenga, 2002, p. 198). A Whitelegge specimen bearing this name is held at NY (W. Buck, pers. comm.): *T.W. Whitelegge*, 1886 (*n.v.*).

Isopterygium teysmannii Broth. = *Taxiphyllum taxirameum* (Mitt.) M.Fleisch.

Hypnum teysmannii Sande Lac., Bryologia Javanica 2: 192, 290. 1868. *Isopterygium teysmannii* (Sande Lac.) A. Jaeger, *Ber. Thätigk. St. Gallischen Naturwiss. Ges* 1876–1877: 433 (1878).

Isopterygium umbillicatulum Mitt., *Trans. & Proc. Roy. Soc. Victoria* 19:86 (1882), *nom. nud.* = *Ectropothecium* sp.

Isopterygium viridepallidus Müll.Hal. *ex* W.Forsyth, *Proc. Linn. Soc. New South Wales* 24: 683 (1900), *nom. nud.* Not found.

Isopterygium walterianum (Hampe) Mitt., *Trans. Roy. Soc. Victoria* 19:86 (1882). *Hypnum walterianum* (Hampe) A.Jaeger, *Ber. Thätigk. St. Gallischen Naturwiss. Ges.* 1877–78: 320 (1880). (Gen. Sp. Musc. 2: 584). Type: Victoria: Mt. Macedon, *Walter* = *Hypnum cupressiforme* Hedw. var. *mossmannianum* (Müll.Hal.) Ando.

Acknowledgments

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The genus *Cycas* (Cycadaceae) in Indonesia

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Abstract

The genus *Cycas* is reviewed for Indonesia. Ten species are enumerated, two of them new (***C. sundaica, C. montana***). Lectotypes are designated for *Cycas* Subsection *Endemicae, C. glauca, C. circinalis* subsp. *riuminiana* var. *curranii* forma *maritima* J.Schust. The species are placed within an infrageneric classification previously outlined. Distribution of all taxa is mapped, and a key to species provided. Extensions into Malaysia (*C. edentata*) and Papua New Guinea (*C. apoa, C. papuana, C. scratchleyana*) are discussed under the species. Previous recordings of *C. circinalis* from Indonesia are discussed.

Introduction

The genus *Cycas* is the single constituent genus of the family Cycadaceae, itself the basal lineage of the living cycads or Cycadophyta (Stevenson 1992). It is also the sole living cycad group occurring in Asia. The only known fossil evidence for this genus is from the Eocene of China and Japan, and this, together with the occurrence of all major lineages in the genus in mainland Asia, supports a long-term presence and probable origin of this genus in that region (Hill 1995b). *Cycas* consists of about 100 species, chiefly Indo-Chinese (about 40 species) and Australian (27 species). The genus also occurs in the Malesian region, Japan and India, extending to Micronesia and Polynesia, Madagascar and East Africa. Plants are commonly understorey shrubs in forest, woodland or savanna habitats. Ten species are known in Indonesia.

The cycad flora of Indonesia is relatively sparse in comparison to Indochina and northern Australia, both of which show extensive local radiations. A similar but smaller radiation, however, appears to have occurred in the Sunda region (Nusa Tenggara) of Indonesia.

Examination of existing herbarium material of the genus *Cycas* L. from Indonesia shows that most specimens are sterile, often incomplete and often hard to assign to any described taxon or even subsection of the genus. This has contributed to the taxonomic confusion, with a number of valid taxa being put into synonymy with unrelated taxa, based upon examination of sterile specimens and inaccurate illustrations. This also highlights the necessity of field studies in this group.

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The present work is the outcome of our separate and combined studies, with a total of three field trips during the period 1999–2000. Herbarium collections held by A, B, BM, BO, E, G, K, L, LAE, NY, P and SING have been examined by at least one author. Terminology is as in previous papers in this series (e.g. Hill 1994a), as are generic and specific concepts applied. Conventions in measurements taken and presented in the following descriptions are as in other papers in this series, and are set out in Lindstrom and Hill (2007). Many of the measurements were made on fresh material; in a few instances these measurements are not given in the descriptions because they were not recorded or fertile material was absent in the field.

Taxonomic history

The genus *Cycas* was first recorded from Indonesia by Rumphius (G.E. Rumpf), with his description of "Olus Calappoides" (1741). The Rumphius plates were then cited by Linnaeus (1753) in his description of *C. circinalis* L., a species in India.

The existence of a distinct Indonesian taxon was first recognised by Roxburgh (1832: 747), who mistakenly applied the name *C. sphaerica* Roxb. to plants from India belonging to the *C. circinalis* alliance (Lindstrom & Hill 2007). The distinct Indonesian taxon he then treated under the name *C. circinalis.*

This Indonesian species was first legitimately recognised by Miquel (1839: 45) as *C. rumphii* Miq., although Miquel was never clear on the specific limits of this taxon. He also described *C. celebica* Miq. (1839: 45), *C. rumphii* var. *timorensis* Miq. (1841: 125) and *C. circinalis* var. *javana* Miq. (1842: 28) but later abandoned all of these (see below). The outcome of Miquel's confusion was a reluctance by many other authors to recognise *C. rumphii* at all, and the name *C. circinalis* has been widely applied to material belonging to the *C. rumphii* alliance up to the present day.

The comprehensive account of the genus by de Candolle (1868) recorded *C. circinalis* var. *javana*, *C. rumphii* and the variety *C. rumphii* var. *timorensis* from Indonesia, and listed *C. celebica* as a species without distinguishing characters. De Candolle had, however, largely followed Miquel's 1851 treatment in developing his account.

Warburg (1900) recognised the presence of a coastal taxon in New Guinea, assigning it to *C. rumphii.* This coastal taxon has also been assigned to *C. circinalis* (White 1923). Koorders (1911) at first used only the name *C. circinalis*, although he later (1913) took up the name *C. rumphii.* Duyster (1927) also used only the name *C. circinalis.* Backer (1925) placed most Javanese material under *C. rumphii*, and Pilger (1926) subsumed all of the Indonesian taxa under *C. rumphii* with no further comment. Ochse (1931) also regarded all Javanese material as *Cycas rumphii.*

Schuster (1932) clearly showed a lack of understanding of most species. He included material of the *C. rumphii* complex in both *C. rumphii* and *C. circinalis* (and in a number of the subspecies and varieties he erected in this species), but also included a range of other sometimes unrelated taxa in his treatments of these two species.

Backer and Bakhuizen van den Brink (1963) recorded only *C. rumphii* from Java.

De Laubenfels and Adema (1998) divided the Indonesian occurrences of the *C. rumphii* complex into *C. rumphii*, *C. celebica* and *C. edentata* de Laub., and applied the names *C. silvestris* K.D.Hill, *C. scratchleyana* F.Muell., *C. javana* (Miq.) de Laub. and *C. riuminiana* Porte ex Regel to material that included some of the *C. rumphii* complex and also the inland forest species. None of these names were wholly correctly applied (see below).

Conservation

Populations of many Asian species appear to have declined, sometimes dramatically, over the past century. However, there is no comparative data to support this impression, and evidence for the decline is largely anecdotal and circumstantial. Several causes for a decline can be observed in action today, however, even though quantitative data on the effects are not available. Two principal threats to cycads exist in Indonesia at present, habitat loss and selective removal of plants from the wild for trade or utilisation. Some, but not all species occur in reserved areas already proclaimed, but enforcement within these areas is sometimes difficult. There is, however, a growing interest in habitat and species conservation within Indonesia, and additional reserved areas are being evaluated and declared.

The notorious Asian cycad scale insect *Aulacaspis yasumatsui,* has been introduced to Timor and is already widespread on Java and Bali. However the wasp that is predatory on the scale seems to be absent from these islands. A similar scenario has occurred in wild cycad populations in Guam and Taiwan (IUCN Cycad Specialist Group 2006) as well as in the U.S.A where the scale is rapidly killing many cultivated cycads (Howard et al. 1999). There is evidence that this pest was introduced many years ago as the once extensive *Cycas* collection in Bogor Botanic Garden, Java, was completely wiped out long ago. The scale is established in West Timor but as yet no scale has been found outside the capital Koupang.

One Indonesian species only (*C. celebica*) was listed in the now out-of-date (for this region) IUCN 1997 Red Book of Threatened Plants (Walter & Gillet 1998). This has now been shown to be conspecific with *C. rumphii* (see below), and is not regarded as seriously threatened. Species treated below are allocated provisional conservation status codes under the new coding system devised by the IUCN (Criteria Version 3.1: IUCN 2001). Conservation status of all species is summarised in Table 1.

Taxonomic treatment

Cycas L., Sp. Pl.: 1188 (1753).

Type: *C. circinalis* L.; lectotype designated by Stevenson in Jarvis et al. (1993).

Dioecious palm-like shrubs with aerial or subterranean, pachycaul, cylindrical stems clad with persistent frond-bases. Fronds loosely pubescent when young, pinnate, spirally arranged, produced in seasonal growth flushes interspersed with cataphylls, lower pinnae often reduced to spines. Longitudinal ptyxis erect or rarely reflexed, horizontal ptyxis circinate. Pinnae with a single thick midrib and no lateral veins; stomata confined to abaxial surface in most species; individual ptyxis involute. Trichomes transparent, branched or simple. Leaves with vascular traces girdling stems, girdling traces not present in cataphylls or megasporophlls. Microsporophylls aggregated into determinate cones and bearing numerous microsporangia (pollen-sacs) on abaxial surfaces, with a simple sterile apex, which is often produced into an upturned spine; microsporangia opening by slits; pollen cymbiform, monosulcate. Megasporophylls spirally arranged in an indeterminate terminal rosette with the central axis continuing vegetative growth. Ovules two to many (rarely one), marginally inserted on the stipe and directed obliquely outwards (ascending); sporophyll apically dilated into a pinnatifid, pectinate, toothed or entire lamina. Seeds with a yellow, orange or brown fleshy outer sarcotesta,

Table 1. Conservation status of Indonesian cycads

	Other Countries	1997 Red List Status	Reserved	IUCN Ver 3.1: 2001 Status (Donaldson 2003)	Pop. Size	Present Decline	Range (km²)	Habitat Reduction (%)
C. apoa	Indonesia & PNG	-	N	NT, LC#	>10,000	?	1000	<20
C. edentata	Thailand	-	N	NT**	>10, 000	?Low	1000	<30
	Vietnam	-	N	NT**				
	Indonesia	-	N	NT**,NT#				
	Malaysia	-	N	NT**				
	Philippines	-	N	DD				
C. falcata		-	N	DD	?	?	500	-
C. glauca		-	?	VU#	?	?	500	-
C. javana		-	N	DD, NT#	?	?	1000	-
C. montana		-	N	NT#	?	?	200	-
C. papuana	Indonesia	-	N	NT	>10,000	?	200	-
	PNG		Y					
C. rumphii	Indonesia	R*	N	NT	>10,000	?low	1,000	20–50
	PNG	-	Y	-	-	-	-	-
C. scratchleyana	Indonesia & PNG	-	N	NT, LC#	>10,000	low	1,000	<20
C. sundaica		-	Y	LC#	>5000	low	500	<20

* as *C. celebica*
** as *C. litoralis* in Indonesia, Malaysia, Thailand, Vietnam (Donaldson 2003)
\# status recommended by authors
C. apoa, C. papuana and *C. scratchleyana* = combined data for Indonesia & PNG
C. edentata figures = combined data for all countries

and with or without spongy tissue beneath the inner woody sclerotesta. Endosperm haploid, derived from the female gametophyte. Embryo straight; with 2 cotyledons that are usually united at the tips and a very long, spirally twisted suspensor; seeds platyspermic; germination cryptocotylar.

Six sections are now recognised: four in Hill (1995b), one additional in Hill (2008) and another one in Lindstrom et al.(2008). There has been disagreement on subgeneric division (Wang 1996, de Laubenfels 1998) and, in the light of improved understanding of the genus, none of the proposed systems would appear entirely adequate (Hill 1998, 2004a, b). Two sections occur in Indonesia. One section is represented by species that occur naturally in Indonesia and a second is represented by one widely cultivated species.

Key to sections

1 Ovules tomentose .... Section *Asiorientales*# (*C. revoluta* Thunb.)

1* Ovules glabrous.......... Section *Cycas*

Key to the species

1 Seeds with a spongy layer inside the sclerotesta.......... [Subsection *Rumphiae*]

  2 Megasporophyll with distinct lateral spines

    3 Leaves openly keeled (opposing leaflets at c. 150°) .... 5. *C. falcata*
    3*Leaves flat (opposing leaflets at c. 180°) .... 8. *C. sundaica*

  2* Megasporophyll lacking distinct lateral spines

    4 Seeds crested; microsporophylls short-spined .... 6. *C. rumphii*
    4*Seeds not crested; microsporophylls long-spined .... 7. *C. edentata*

1* Seeds lacking a spongy layer

  5 Leaves glaucous [Subsection *Endemicae*] .... 9. *C. glauca*
  5* Leaves green, not glaucous

    6 Petiole spinescent; leaflets with margins slightly recurved; new shoots not bluish .... [Subsection Cycas]

      7 Lateral spines on megasporophyll lamina obscure or absent.......... 1. *C. apoa*
      7* Lateral spines on megasporophyll lamina present, distinct

        8 Megasporophyll lamina narrow (less than 35 mm wide)

          9 Leaflets broad (> 10 mm wide) .... 3. *C. javana*
          9* Leaflets narrow (<10 mm wide) .... 4. *C. montana*

        8* Megasporophyll lamina broad (more than 35 mm wide).......... 2. *C. scratchleyana*

    6* Petiole smooth, not spinescent; leaflets with margins flat; new shoots bluish [Subsection *Endemicae*] .... 10. *C. papuana*

#widely cultivated in Indonesia, not discussed further in this treatment.

Cycas section *Cycas*

Section *Lemuricae* Schuster, Pflanzenr. 99: 65 (1932), nom. illegit.

Section *Cycas* is defined by the combination of glabrous ovules, a non-pectinate megasporophyll lamina and hard & woody mature male cones. Three subsections are recognised, circumscription following Hill (1995b), with all occurring in Indonesia. The full range of the section is from India and southern Indochina south to Australia, and from East Africa east to Tonga.

Key to the subsections

1 Seeds with a spongy layer inside the sclerotesta .... Subsection *Rumphiae*

1*Seeds lacking a spongy layer

  2 Sarcotesta of seed with fibrous layer present (Indonesian species)......... Subsection *Cycas*

  2*Sarcotesta lacking a fibrous layer.. Subsection *Endemicae*

Cycas subsection *Cycas*

This subsection of about 12 species is defined by the absence of a spongy endotesta, the presence of fibres in the sarcotesta, and the narrow megasporophyll lamina. Seeds have not been seen in *Cycas javana* and *C. montana*, but they fit this section in other ways (leaf and megasporophyll characters), and are assumed to possess the fibrous sclerotesta of the group. The group (subsection) ranges from India and Sri Lanka to Luzon, and south and east to New Guinea. Most representatives are plants of closed forests, usually on ridges away from the coast. Four species occur in Indonesia (Fig. 1).

1. *Cycas apoa* K.D.Hill, Austral. Syst. Bot. 7(6): 553–554 (1994).

Type: Indonesia, Papua, Babrongko, S. coast of Lake Sentani, *G. Iwanggin BW 5245*, 4 Apr 1957 (holo CANB; iso A, BRI, LAE, L).

Literature: de Laubenfels and Adema (1998 as *C. scratchleyana*)

Illustration: Hill (1994a, fig. 9).

Etymology: a rendering of the local vernacular name for this taxon in the Kaka language, as spoken around the Sepik estuary in north-western New Guinea. It is pronounced AP-wah, with the first syllable stressed but short, as in 'cap'.

Vernacular: *handambo* (Sentani language), *apoa* (Kaka language, Kasmin village) (Hill 1994a).

Stems arborescent, to 2.5 m tall. *Leaves* bright green, highly glossy, 180–250 cm long, flat (not keeled) in section (opposing pinnae inserted at 180° on rachis), densely and loosely tomentose with white and orange trichomes shedding as leaf expands; terminated by a spine or paired leaflets to 4 mm long; petiole 35–60 cm long, glabrous, spinescent for 80–100% of length; basal leaflets not gradually reducing to spines, 140 mm long. *Median leaflets* simple, strongly discolorous, 220–320 mm long, 11–15 mm wide, inserted at 70–80° to rachis, decurrent for 7 mm, narrowed to 2.5 mm at base (to 20% of maximum width), 13 mm apart on rachis; section flat; margins slightly recurved, often undulate; apex softly acuminate, not spinescent; midrib raised above, raised below. *Cataphylls* linear, soft, pilose. *Pollen cones* narrowly ovoid, orange; microsporophyll lamina firm, not dorsiventrally thickened, apical spine not prominent, upturned. *Megasporophylls* 20–26 cm long, orange and grey tomemtum; ovules 2–8, glabrous; lamina lanceolate, c. 35 mm long, c. 16 mm wide, lateral spines not developed, apical spine 15–30 mm long. *Seeds* flattened-ovoid, 45–50 mm long, 40 mm wide; sarcotesta orange-brown, not pruinose, 3–5 mm thick; fibrous layer present; sclerotesta smooth; spongy endotesta absent. Fig. 2.

Historical notes: included in *C. scratchleyana* by de Laubenfels and Adema (1998).

Distinguishing features: *Cycas apoa* is distinguished by the thin leaflets with narrow bases and no laminar hypodermis, continuous adaxial and abaxial hypodermis and strongly undulate margins, and the small megasporophyll lamina with reduced or no lateral spines (Fig. 2). *Cycas scratchleyana* from the southern side of New Guinea shares the thin, undulate leaflets, but has a much larger and relatively broader megasporophyll apex with numerous clearly defined lateral spines. The two also share continuous adaxial mesophyll and sometimes continuous abaxial mesophyll. The midrib is also narrow and usually sharply raised in both taxa. This is the species sometimes referred to as *C. circinalis* in northern coastal New Guinea (Borrell 1989).

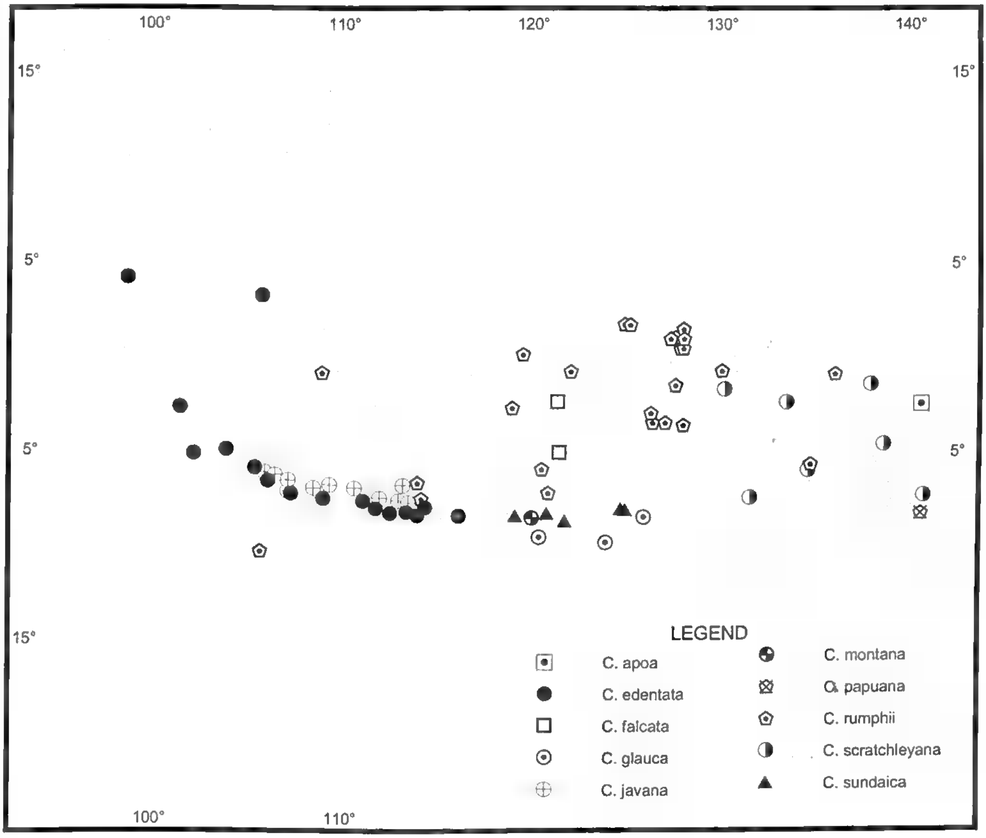

Fig. 1. Distribution of the genus *Cycas* in Indonesia.

Although the reduced lateral spines on the megasporophyll are given as a diagnostic character, some cultivated plants have shown distinct small lateral teeth on the sides of the apical spine on the megasporophyll. However, these teeth are not present on the main part of the lamina.

Distribution and habitat: known from northern coastal New Guinea, from the Huon Peninsula west to the Jayapura Regency (Fig. 1). This species occupies much the same geographic range as *C. rumphii* in this area, and detailed field study would be required to determine the controls on distribution. *Cycas rumphii* is, however, a primarily littoral species, whereas *C. apoa* apparently occurs away from the littoral zone.

This species and *C. scratchleyana* were included in subsection *Rumphiae* by Hill (1994a) on the basis of the limited and apparently mixed seed collections then available. At that time, section *Cycas* was not known to extend beyond Malaysia. More recent, collections and further studies have clearly established placement of these species and *C. javana* in subsection *Cycas* (sensu Hill 1995b), and dramatically extended the known range of this subsection.

Sporadic and scattered, in more or less closed mesophyll forest in wet lowland areas, sometimes in seasonally inundated sites but more often on low ridges.

Conservation status: not considered to be at risk. Recommended status would be **LC.** Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003) for Indonesia and PNG.

Selected specimens examined: PAPUA NEW GUINEA: West Sepik: Kasiman Village, *Ferrero s.n.*, 1993 (NSW). **Morobe:** Quembung trail, *Clemens 8104*, 2 Apr. 1938 (A[n.v.], BRI, CANB, L); Sattelberg, *Clemens 751*, 31 Oct 1935 (G).

2. ***Cycas scratchleyana*** F.Muell., Victorian Naturalist 2(2): 18–19 (1885). *Cycas circinalis* subsp. *papuana* var. *scratchleyana* (F.Muell.) J.Schust., Pflanzenr. 99: 70–71 (1932).

Type: Papua New Guinea, Central: "New Guinea, Mt. Bedford, Jala River, Dedouri-Country", *W. Armit s.n.* (holo MEL; iso K).

Literature: Thistleton-Dyer (1888 as a form of *C. rumphii*), Lauterbach (1900 as *C. circinalis* in part), White (1923, as *C. circinalis*), de Laubenfels & Adema (1998), Hill (1994a).

Illustrations: Mueller (1885b), Schuster (1932, fig 10K), Hill (1994a, fig. 13).

Etymology: honouring English military engineer and colonial administrator Sir Peter Henry Scratchley (1835–1885), Special Commissioner for the Territory of New Guinea from 1884–1885.

Vernacular: *bico* (Ekor village, Halmahera), *enge-enge* (Mekeo language, Maipa village), *notuweh* (Medino village), *kataki* (Dsimakani language, Lake Murray area) (Hill 1994a).

Stems arborescent, to 4, rarely 7 m tall, 12–20 cm diam. at narrowest point. *Leaves* bright green or deep green, highly glossy, 170–310 cm long, flat (not keeled) in section (opposing pinnae inserted at 180° on rachis), with 160–300 leaflets, with white tomentum shedding as leaf expands; rachis usually terminated by a spine or paired leaflets; petiole 25–70 cm long (20–30% of total leaf), glabrous, spinescent for 80–100% of length; basal leaflets not gradually reducing to spines. *Median leaflets* simple, strongly discolorous, 220–310 mm long, 10–16 mm wide, inserted at 60° to rachis, decurrent for 1 mm, narrowed to 2.5 mm at base (to 20% of maximum width), 16 mm apart on rachis; section flat; margins slightly recurved and undulate; apex softly acuminate, not spinescent; midrib raised above, raised below. *Cataphylls* linear, pungent, pilose, 50–100 mm long. *Pollen cones* narrowly ovoid or fusiform, yellow to brown (pale), 20–25 cm long, 10–13 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, c. 35 mm long, c. 20 mm wide, fertile zone c. 27 mm long, sterile apex c. 6 mm long, raised; apical spine prominent or rudimentary, sharply upturned, 2–6 mm long. *Megasporophylls* c. 28 cm long, orange-brown tomentum; ovules 2–8, glabrous; lamina ovate to lanceolate, 45–80 mm long, 38–50 mm wide, regularly dentate; with 28–40 soft lateral spines 5–8 mm long, 1 mm wide; apical spine distinct from lateral spines, 25–30 mm long, 3 mm wide at base. *Seeds* flattened-ovoid, 43–55 mm long, 32–40 mm wide; sarcotesta orange or orange-brown, not pruinose, 5–7 mm thick; fibrous layer present; sclerotesta smooth; spongy endotesta absent. Fig. 2.

Historical notes: described in 1885 by German-born but pre-eminent Australian colonial botanist Sir Ferdinand Jacob Heinrich von Mueller (1825–1896). Collection details cited were "On Mount Bedford, Jala-River, Dedouri-Country; W. Armit." The single specimen known, which can be accepted as the holotype, is MEL 68059 (photo NSW), collected by W.E. Armit on the Argus Expedition into the hinterland of Port Moresby in 1883. The label reads as cited by Mueller, without the "On" preface, although Mount Bedford and Jala River were treated as separate localities by Mueller in a listing of Armit collections appended to the protologue. The label was also written entirely in Mueller's hand. Schuster cited "Mount Bedford, Jala-River (Rev. James Chalmers in Herb. Sidney); Dedouri-Country (W. Armit in Herb. Sidney)." None of these specimens can be found in NSW. An isotype, sent by Mueller, is held by K.

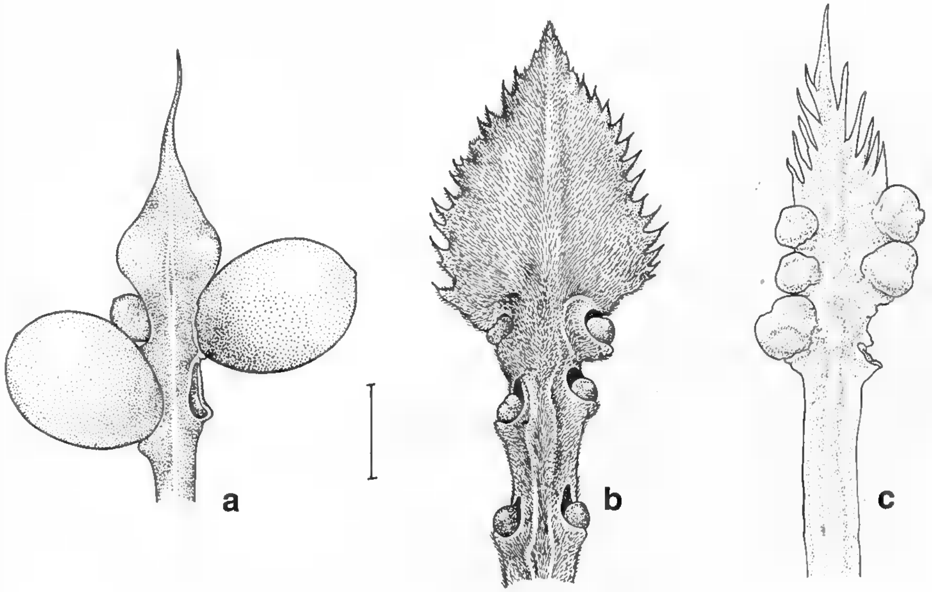

Fig. 2. Comparison of female sporophylls. **a,** *Cycas apoa*. **b,** *Cycas scratchleyana*. **c,** *Cycas javana* (a from *Ferrero s.n.* by N. Oram, b from *Taylor 11* by N. Oram, c from slide, cult. Cibodas Botanic Garden, Java, Indonesia by C. Wardrop). Scale bar = 2 cm.

This species has been poorly understood since it was first described. Subsequent authors have generally ignored the name *C. scratchleyana*, most commonly using the name *C. circinalis* (Lauterbach 1900, White 1923). Thistleton–Dyer (1888) regarded it as a form of *C. rumphii*. The treatment by Schuster (1932) regarded *C. scratchleyana* as a variety of *C. circinalis* within subspecies *papuana* (F.Muell.) Schuster, effectively combining the three subsections of section *Cycas* in a single species.

Schuster's treatment has not been generally followed, although attempts to follow it in the Pacific were made by Smith (1979) and Kanehira (1938). More recently, there has been a tendency to apply the names *C. rumphii*, *C. circinalis* and, to a lesser extent, *C. media* R.Br. somewhat uncritically, including to specimens of *C. scratchleyana* (Paijmans 1976; specimen determinations in LAE, CANB, L, BO). The treatment of *Cycas* by de Laubenfels and Adema (1998) recognises *C. scratchleyana*, but with unclear circumscription and citing material that clearly does not belong (e.g. *Warburg 21129* from New Britain). Mistaken inclusion of *C. scratchleyana* in subsection *Rumphiae* by Hill (1994a) is discussed above under *C. apoa*.

Distinguishing features: nearest to *C. apoa*, from which it is distinguished as discussed above. Distinguished within the genus by the relatively large, ovate megasporophyll lamina with numerous short to medium-length lateral spines, the long, narrow, thin leaflets that lack hypodermis and are frequently very strongly undulate, and the usually wholly spinescent petiole. Adaxial mesophyll is continuous across the usually narrow and strongly raised midrib, and abaxial mesophyll also is sometimes continuous. Some specimens display broader, harder leaflets with scattered laminar hypodermis, probably as an environmental response to higher light conditions. Some specimens from around Port Moresby also show somewhat narrower, harder and slightly keeled leaflets with a harder and glossier cuticle, and are interpreted as the products of hybridism with *C. campestris* K.D.Hill.

Distribution and habitat: widespread in eastern New Guinea, extending from near-coastal sites to foothills, from Milne Bay west to western Irian Jaya and Maluku, apparently mainly on the southern catchments (Fig. 1). Collections from Irian Jaya are limited, and the species is probably more abundant than is suggested. The range also may extend further to the west. Often a species of higher elevations (to over 900 m), usually on slopes or ridges in more or less closed, moist forests, but also extending to similar forests on stabilised calcareous coral-sand dune country and nearby headlands, particularly in the east of the range.

Plants from the far west of the known range (*Buwalda 4622*) from the Tanimbar group) show a somewhat narrower megasporophyll lamina, but still with the distinct dentition of *C. scratchleyana*. These may represent regional variation, some degree of intergradation with *C. javana*, or another taxon. Widespread regional political unrest has rendered this locality off limts for some time now. These plants require further investigation, but are here treated as a regional variant of *C. scratchleyana* until such time as they can be adequately investigated.

Conservation status: not considered to be at risk. Recommended status would be **LC.** Ver 3.1:IUCN (2001) status is **NT** for Indonsesia and PNG. (Donaldson 2003).

Selected specimens examined: PAPUA NEW GUINEA: Milne Bay: Biniguni camp, Gwariu River, *Brass 23830*, 5 Aug 1953 (A[n.v.], CANB, K, L); track between Tutubea and Lake Lavu, Fergusson Island, Esa'ala Subdistrict, *Croft et al. LAE 68785 A*, 12 Nov 1976 (LAE, BRI, CANB, K, L); top of Pini Range, Sagarai, Alor Subprovince, *Gideon LAE76964*, 3 Mar 1984 (LAE, K, L); 2 km inland of Medino, N coast of Cape Vogel Peninsula, *Hoogland 4750*, 15 Sep 1954 (CANB, BM, BO, BRI, K, L, LAE); Sewa Bay, Normanby Island, Ese'ala Sub-district, *Lelean and Streimann LAE 525246*, 21 Oct 1971 (ALE); Biniguni, Raba Raba Subdistrict, *Streimann NGF28556*, 27 Jun 1972 (LAE[n.v.], CANB, K, L); near Kwagira, *Taylor 11*, 26 Sep 1954 (CANB). **Central:** Kubuna, *Brass 5643*, Nov 1943 (BRI, BO); near Maipa airstrip, Maipa village, Kairuku Subdistrict, *Darbyshire 907*, 8 Sep 1962 (CANB, K, L, LAE); on ridge below Boridi Village, Port Moresby Subdistrict, *Foreman and Vinas LAE60256*, 1 Oct 1973 (LAE, CANB, K, L); logging road near Kuriva sawmill, Hiritano Highway road, Moresby Subdistrict, *Larivita and Maru LAE70598*, 1 Sep 1976 (LAE, BRI, K, L, NSW); Mekeo district, *White 794*, Jul–Aug 1918 (BRI); Brown River timber reserve, *Womersley & Van Royen NGF5872*, 24 Jun 1954 (BO). **Gulf:** near Malalaua, *Craven and Schodde 933*, 2 Mar 1966 (CANB, K, L, LAE); above Purari, 63 km at 65 deg. from Baimuru, Baimuru Subdistrict, *Croft et al.LAE 61174*, 27 Mar 1974 (LAE, BRI, CANB, K, L); Mina River, Kikori Subdistrict, *Womersley NGF46475*, 28 Mar 1974 (LAE, BRI, CANB, K, L). **Western:** Fly River, 528 mile camp [Palmer Junction], *Brass 6752*, May 1936 (A, BM, BO, BRI, K, L, LAE); Kiunga, Kiunga Subdistrict, *Streimann and Lelean NGF34119*, 13 Sep 1972 (LAE[n.v.], CANB, L).

INDONESIA: Papua: Mamberamo River nr Albatros bis, *Docters van Leeuwin 9623*, Jul 1926 (BO); Jaba, Wissel Lake region, *Eyma 5451*, 23 Nov 1939 (BO);Merauke District: path from Lake Wam to Wam River, *van Royen 4769*, 21 Aug 1954 (L, CANB, KEP K). Radjah Ampat, Waigeo Island, Siam River on eastern peninsula upstream of Wekasan, *van Royen 5297*, 25 Jan 1955 (L, CANB). **Maluku:** Aru, Kobroor, *Durbaum s.n.*, Aug 1995 (NSW); Halmahera, Ekor, base of Gunung Panjang, *Vogel 3136*, 24 Sep 1974 (L, CANB); Tanimbar, Jamdona Is., Otimmer, *Buwalda 4622*, 5 Apr 1938 (BO, K, L). **West Papua:** Misool Is., Sorong [1° 48'S 130° 08'E], on road to Tip, *Pleyte 978*, 21 Sep 1948 (BO, BRI, K);

3. *Cycas javana* (Miq.) de Laub., in D.Y.Wang, Cycads China: 65 (1996). *Cycas circinalis* var. *javana* Miq., Monogr. Cycad.: 28. Tab. 1, fig. t & u, Tab. II, fig. E1 (1842).

Type: Indonesia, Java, *Blume 1089* (holo L, 2 sheets).

Literature: De Candolle (1868 as *C. circinalis* var. *javana*), Miquel (1868 as *C. rumphii*).

Illustrations: Miquel (1842 as *C. circinalis* var. *javana*) de Laubenfels (in Wang 1996, figs 1-5), de Laubenfels and Adema (1998, fig 2).

Etymology: from the island of Java, with the Latin suffix -ana, a connection, referring to its occurrence on and initial collection from Java.

Stems arborescent, 2–4 m tall, 15–20 cm diam. at narrowest point. *Leaves* dark to mid green, highly glossy, faintly bluish as expanding, to 205 cm long, flat (not keeled) in section (opposing pinnae inserted at 180° on rachis), with c.146 leaflets, with brown or orange-brown tomentum shedding as leaf expands, terminated by a spine to 6 mm long or paired leaflets; petiole 30–60 cm long (15–25% of total leaf length), glabrous, spinescent for 40–90% of length; basal leaflets not gradually reducing to spines. *Median leaflets* simple, strongly discolorous, 240–370 mm long, 10–15 mm wide, inserted at c. 50° to rachis, narrowed to 2.5–6 mm at base (to 20–35% of maximum width); section flat; margins slightly to moderately recurved; apex acute, not spinescent; midrib raised above, raised below. *Cataphylls* linear, soft, rich orange-brown pilose. *Pollen cones* ovoid, orange or brown; microsporophyll lamina firm, not dorsiventrally thickened, apical spine prominent, sharply upturned. *Megasporophylls* 22–36 cm long, brown-tomentose, tomentum persistent; ovules 2–8, glabrous; lamina lanceolate, 60–100 mm long, 11–30 mm wide, regularly dentate; with 12–30 pungent lateral spines 5–20 mm long, 1–2 mm wide; apical spine distinct from lateral spines, 10–65 mm long, 1.5–3 mm wide at base. *Seeds* not seen. Fig. 2.

Historical notes: described in 1842 as a variety of *C. circinalis* by Dutch botanist Miquel. Miquel later subsumed this variety into *C. rumphii*, and no further note was made of it until the present decade when de Laubenfels raised this to species in 1996. The treatment of this species by de Laubenfels and Adema (1998) is essentially correct.

Distinguishing features: the lack of any spongy endotesta and the narrow, regularly-toothed megasporophyll lamina distinguish this species.

Distribution and habitat: *Cycas javana* is apparently a Javan endemic (Fig. 1). Plants occur in closed evergreen forest, inland, often near streams in mountain areas. Populations also persist in disturbed areas.

Conservation status: much of the original habitat of this species has been cleared for agriculture. Although healthy populations remain in some higher areas, the appropriate recommended status would be **NT.** Ver 3.1:IUCN (2001) status is **DD** (Donaldson 2003).

Selected specimens examined: INDONESIA: Jawa Timur: Kangean, [--] Tanbajangan [Tambayangan] 22 m, *Backer 27471*, 1920 (L, BO); Kangean Is., NE of Java, *Hoogerwerf 235*, 1954 (L); Besoeki Poeger [Besuki Puger], [G.] Watangan [8° 25'S 113° 28'E], *Koorders 1564 B*, 21 Aug 1889 (L, BO). **Jawa Tengah:** Prov. Banjoemas, Pringombar, *Koorders 1563*, 20 Nov 1891 (L, BO); Prov. Preangar, Temarang [?Semarang], Kedoengdjati [7° 10'S 110° 38'E], *Koorders 24990 B*, 19 Sep 1896 (L).**Jawa Barat:** Banham Tusschen Malingping [6° 48'S 106° 01'E] en Penjarroengan [Panggarangan 6° 53'S 106° 12'E], *Backer 1476*, 17 Jun 1911 (L); Tjialin a/d Tjitarik [6° 20' S 107° 27' E], Res Oreabgar, 500 m, *Bakhuizen v.d. Brink 5086*, 21 Dec 1920 (L); G. Talagabodas (7° 12'S 108° 28'E), *Ken VH* (L); near Cibaraja village, along stream, 7°22.164'N 107°08.580'E, *Lindstrom 174, 175* (live voucher plants at Nong Nooch Tropical Botanical Gardens); cult. in Cibaraja village, coll. nearby, *Lindstrom 173*, Apr 1999 (NSW, UBC); Res Preangar, Reg Tjabareno estate, by pelaboean Ratoe [Pelabuhan Ratu 6° 59'S 106° 35'E], *Pottinga s.n.*, 1 Oct 1923 (L, BO); Kuripia [? Koeripan - near Bogor], *leg. ign.* (L); Kuripau [? Koeripan - near Bogor], *leg. ign.* (L); Up Kuripian [? Koeripan - near Bogor], *leg. ign. [Blume?] 1079* (L).

Cult.: hort. Bogor, *Stolk 149* (BO, L)

4. *Cycas montana* A.Lindstr. & K.D.Hill, sp. nov.

Inter species indonesienses combinatione characterum sequentium distinguitur: folia viridia (non glauca), foliolis rigidis angustis, petiolis tomentosis, fructus non spongiosus.

Type: Indonesia, Flores, Mangarai province, Nggoang district, Ndara, Wae Moto village, 400 m, *Lindstrom 248*, 27 Apr 2000 (Holotype BO, iso UBC).

Etymology: from the montain habitat.

Vernacular: *tulumpu*, *watai* (unidentified languages).

Stems arborescent, to 1.5 m. tall, 30–35 cm diam. at narrowest point. *Leaves* deep green, glossy, 223–248 cm long, 144–151 leaflets, with persistent brown tomentum; petiole 63–72 cm long (25–30% of total leaf), spinescent for c. 20% of length; basal leaflets not gradually reducing to spines, to 230 mm long. *Median leaflets* simple, strongly discolorous, 230–248 mm long, 8–10 mm wide, decurrent for 7 mm, narrowed to

3–4 mm at base (30–40% of maximum width), 10–15 mm apart on rachis; section slightly keeled; margins distinctly recurved; apex acute or aristate, spinescent; midrib flat above, raised below, narrow. *Cataphylls* narrowly triangular, soft. *Pollen cones* not seen. *Megasporophylls* 20–35 cm long, tomentum orange, persistent; ovules 2–6, glabrous; lamina lanceolate, 45–100 mm long, 20–40 mm wide, shallowly pectinate, with 14–40 pungent lateral spines 9–13 mm long, 1.5 mm wide; apical spine distinct from lateral spines, 25–40 mm long, 5–8 mm wide at base. *Seeds* ovoid, 50–55 mm long, 30–45 mm wide; sarcotesta amber-brown, not pruinose; fibrous layer present; sclerotesta smooth, spongy endotesta absent. Fig. 3.

Distinguishing features: *Cycas montana* is distinguished from other species in the region by the absence of a spongy endotesta, the green (non-glaucous) leaves, the persistent brown tomentum on the petiole, and the stiff, narrow leaflets.

Distribution and habitat: endemic on Flores (Fig. 1), restricted to inland montane forests at higher altitudes.

Conservation status: not thought to be at risk, although not reserved. Recommended Ver 3.1:IUCN(2001) status would be **NT.**

Selected specimens examined: INDONESIA: Nusa Tenggara Timur: Flores: Ngada province, cult. in Bajawa town, said to originate from nearby montain forest, *Lindstrom 253,* 29 Apr 2000 (BO, UBC); Ngada province, cult. in Jerebao village, near Bajawa town, said to come from nearby forest, *Lindstrom 261,* 29 Apr 2000 (BO, UBC); Ngada province, cult. in Wolosambi village, near Bajawa town, said to comefrom nearby forest, *Lindstrom 262,* 30 Apr 2000 (BO, UBC); Ngada province, Nangamboa village, Ondorrea Mountain *Lindstrom 263,* 30 Apr 2000 (BO, UBC); Nunang, 650 m, *Schmutz 0123*, 17 May 1965 (L); Manggarae, Nunang, 650 m, *Schmutz SVD 4717*, 14 Dec 1980 (L).

Cycas* subsection *Rumphiae K.D.Hill, Austral. Syst. Bot. 7: 548 (1994a).

Type species: *Cycas rumphii* Miq., Bull. Sci. Phys. Nat. Neerl. 2: 45 (1839).

This subsection is uniquely defined by the presence of a layer of spongy tissue within the seed. Another potentially synapomorphic character defining this group is the 2-year seed maturation period, although this has been confirmed only for *C. seemannii* A. Br., *C. thouarsii* R. Br. Ex Gaudich.and *C. bougainvilleana* K.D.Hill. All other species of *Cycas* for which data is available have a maturation period of less than one year.

Distribution is very wide, extending from Africa to Fiji and Tonga, and from New Guinea north to southern coastal Indochina. Four species occur in Indonesia.

The spongy endotesta causes seeds to be buoyant, and has been proposed as a dispersal mechanism (Dehgan & Yuen 1983). This dispersal mechanism has been interpreted as a cause of the taxonomic complexity of this group, with successive colonisation events producing the high local variability in some populations and the very different forms sometimes occurring in close proximity (Hill 1994a, Fosberg & Sachet 1975).

5. *Cycas falcata* K.D.Hill, Kew Bull. 54(1): 209 (1999).

Type: Indonesia, Sulawesi, Kabaena, Gunung [Mount] Katopi, 18 km NW of Tangkeno, *McDonald & Ismael 4184*, 7 Aug 1993 (holo K, iso A, BO, E, KEP, L).

Illustrations: Hill (1999).

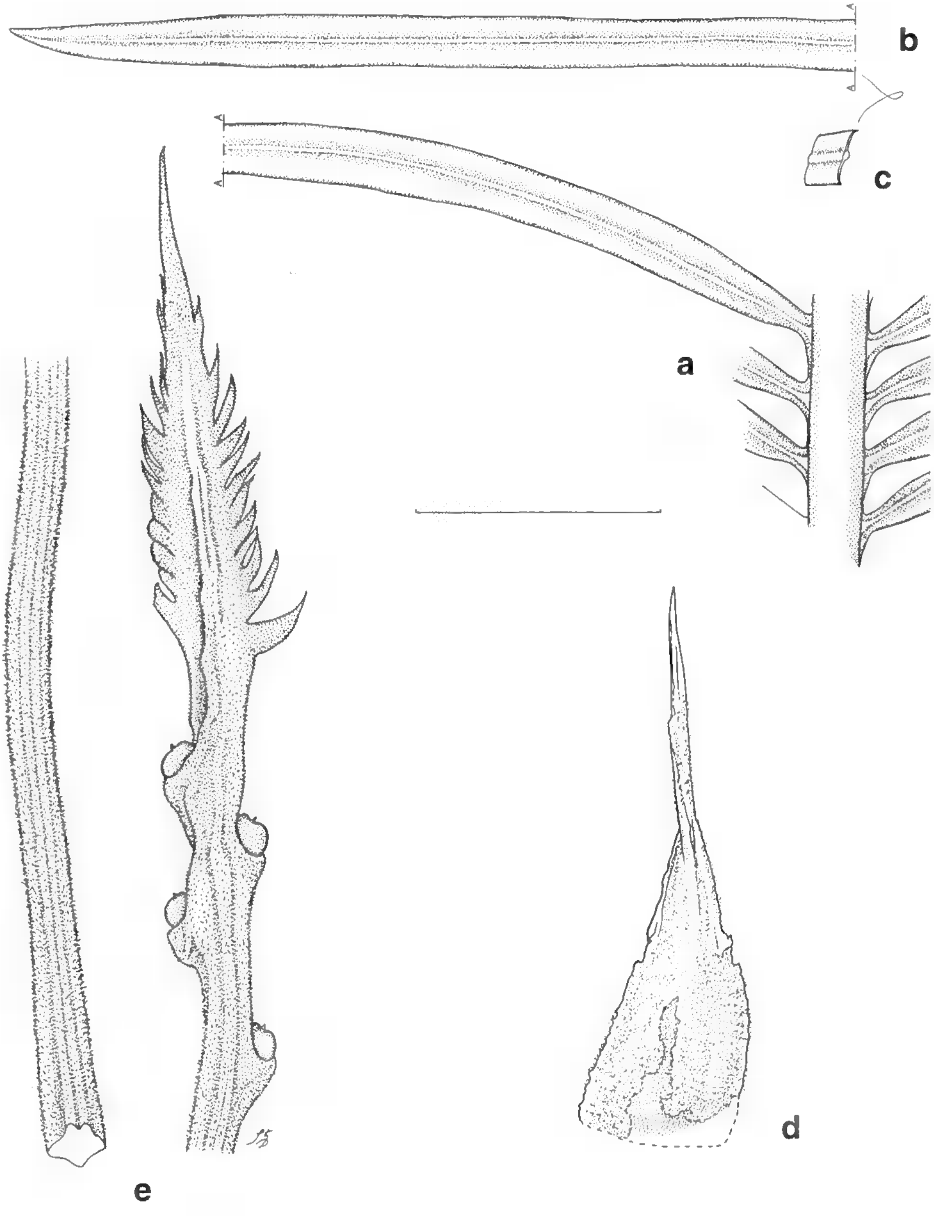

Fig. 3. *Cycas montana.* **a, b,** part of leaf. **c,** cross-section of leaflet. **d,** cataphyll. **e,** female sporophyll (all from *Lindstrom 248*, d, by C. Wardrop). Scale bar = 5 cm.

Etymology: from Latin *falcatus*, falcate or curved in a sickle-shape, from the distinctively curved leaflets.

Stem erect, unbranched or occasionally branching 2 to 3 times at base, to 5 m tall, 12–30 cm diam. at narrowest point. *Leaves* olive-green, glossy, 180–300 cm long, slightly keeled in section (opposing leaflets inserted at c. 150° on rachis), with 100–200 leaflets, glabrous; rachis terminated by paired leaflets or a spine c. 3 mm long; petiole 27–62 cm long (20–35% of total leaf length), glabrous, spinescent for 80–100% of length; basal leaflets not gradually reducing to spines. *Median leaflets* simple, glabrous, moderately discolorous, often strongly falcate, 170–300 mm long, 7.5–13 mm wide, inserted at 60–70° to rachis, decurrent for 5–7 mm, narrowed to 3–4 mm at base (to 45% of maximum width), 11–17 mm apart on rachis; keeled in section; margins slightly recurved; apex acuminate, not spinescent; midrib strongly raised above, green, slightly raised below; leaflets tapering gradually from near midpoint to base; tomentum loose and shed early. *Cataphylls* broadly triangular, soft, 40–70 mm long, with short, erect mid-brown indumentum. *Pollen cones* not seen. *Megasporophylls* 19–27 cm long, mid-brown-tomentose; ovules 4–6, glabrous; lamina narrowly triangular, 60–70 mm long, 22–32 mm wide, shortly pectinate, with 16–28 more or less pungent lateral spines 7–12 mm long; apical spine distinct from lateral spines, 15–28 mm long, 2.5–4 mm wide. *Seeds* flattened-ovoid, 42–46 mm long, 25–34 mm wide; sarcotesta orange-yellow, not pruinose, fibrous layer absent; sclerotesta not or weakly apically crested; thin spongy layer present. Fig. 4.

Distinguishing features: the spongy endotesta places this species unmistakably in the *Cycas rumphii* group (subsection Rumphiae, Hill 1994a), although it differs markedly in many other respects. The small seeds are not typical of this group, and neither are the distinct long lateral spines on the megasporophyll lamina, the keeled leaves or the narrow, falcate pinnae.

Distribution and habitat: *Cycas falcata* is known from two localities on the main island of Sulawesi and from Kabaena Island off the south-eastern coast of Sulawesi (Fig. 1). It occurs in habitats ranging from closed forest to open short tree savanna with grasses dominant, in full sun to heavy shade, over limestone or serpentinite substrates.

The habitat of this species is quite different to the habitats of other species in the *C. rumphii* group, which generally occur in near-coastal situations (Hill 1994a). Aquatic dispersal and the consequent coastal distribution are general features of this group. The departure of this species from the general state can be best regarded as an evolutionary advance, represented by the colonisation of a new and different site. Although many cycads are either calciphiles or serpentiniphiles (Hill 1995b, 1998), such habitat preference can be seen from this example to be derived rather than ancestral conditions, and is a condition that has arisen independently on more than one occasion.

The deeply dentate or shortly pectinate megasporophyll is another feature not known elsewhere in subsection Rumphiae. Similar megasporophylls occur in the forest species *C. macrocarpa* Griff. from Thailand and peninsular Malaysia, and *C. riuminiana* Porte ex Regel from the Philippines. These however lack the spongy endotesta and possess a fibrous sarcotesta not evident in subsection Rumphiae. A hybrid origin between one species of subsection Rumphiae and one of subsection Cycas cannot be demonstrated at this stage, but is not out of the question.

Conservation status: although probably not immediately threatened, this species is of apparently limited distribution and potentially vulnerable in the longer term. On the basis of a preliminary evaluation, the appropriate Ver 3.1:IUCN (2001) status would be **NT**. Further field study is required to fully assess the conservation status of this species and indeed of most Asian cycad species. Current Ver 3.1:IUCN (2001) status is **DD** (Donaldson 2003).

Selected specimens examined: INDONESIA: Sulawesi Selatan: Soroako - Wasuponda road, km 19, *van Balgooy 3930*, 7 Jul 1979 (L, BO); Mt Molinowe, 14 km from Wasuponda between Wasuponda and Soroako, *Hennipman 6133*, 7 Jul 1979 (BO, L, A); S of Wasuponda, SW of Soroako, *de Vogel 6304*, 16 Jul 1979 (L, BO); S. shore of Lake Matano, *de Vogel 5734*, 12 Jun 1979 (L, BO, BRI). **Sulawesi Tenggara:** around Opa Swamp, Mt Makaleo, *Prawiroatmodjo & Soewoko s.n.* and *1757*, 13 Nov 1978 (L ex BO).

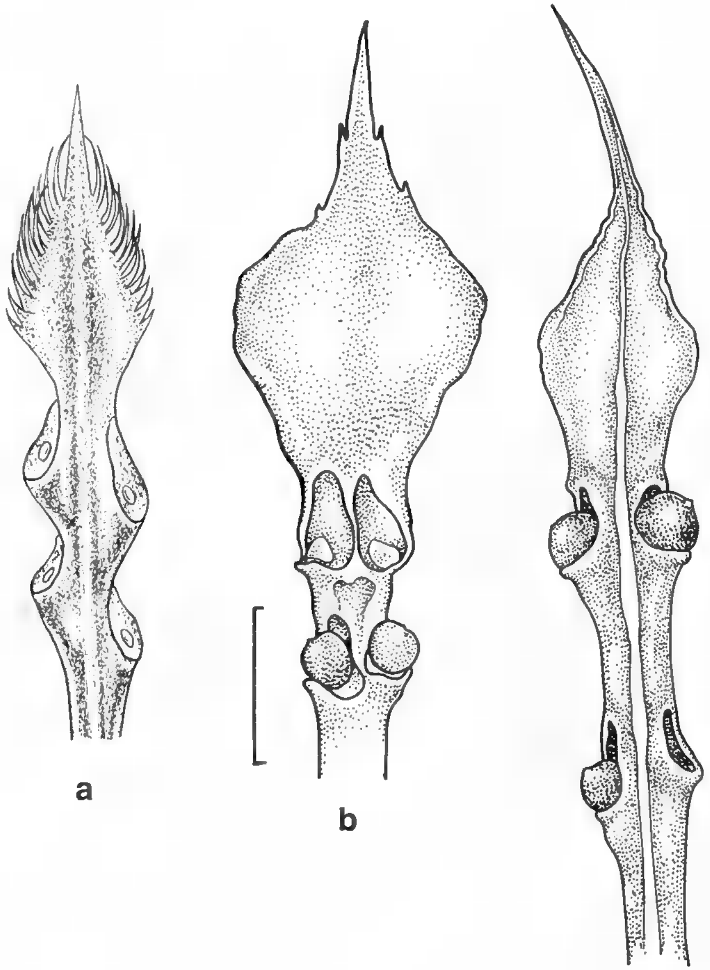

Fig. 4. Comparison of female sporophylls. **a,** *Cycas falcata*. **b,** *Cycas rumphii*. **c,** *Cycas edentata* (a from *McDonald & Ismael 4184* by L.McGurr, b from *van Royen 3300* by N. Oram, c from *Hill 4627* by N. Oram). Scale bar = 2 cm.

6. *Cycas rumphii* Miq., Bull. Sci. Phys. Nat. Néerl. 2: 45 (1839).

Lectotype: Plate 23 in Rumphius (1741), *fide* Lindstrom (2002).

Cycas celebica Miq., Bull.Sci. Phys. Nat. Neerl.2: 45 (1839).
Lectotype: Plate 21 in Rumphius (1741), *fide* Lindstrom (2002).

[*Cycas recurvata* Blume ex. J. Schuster., Pflanzenr. 99:74 (1932); name only, in syn. *Cycas rumphii*]

[*Cycas speciosa* D. Don, Proc.Linn.Soc. 1:53–56 (1840); name only, in syn. *Cycas rumphii*]

[*Cycas sundaica* Miq. ex J. Schust., Pflanzenr. 99: 74 (1932); name only, in syn. *Cycas rumphii*]

Literature: Lemaire (1864 as *C. rumphii* and *C. celebica*), Lauterbach (1900 as *C. circinalis*), Stapf (1916), Backer (1925), Ochse (1931), Schuster (1932), Kanehira (1938), Backer & Bakhuizen van den Brink (1963), Peekel (1984), Hill (1994a), de Laubenfels and Adema (1988, in part).

Illustrations: Miquel (1852), Warburg (1900), Schuster (1932), Kanehira (1938),Peekel (1984), Hill (1994a).

Etymology: honouring German-born Dutch naturalist Rumphius (Georg Eberhard Rumpf, 1628-1702), military officer with the Dutch East India Company in Ambon, 1652–1657, then with the civil merchant service of the Dutch East India Company.

Vernacular: *nufuès* (Biak); queen sago (English); *haji, hajo, intalappana, pakoe laut* (sea fern), *paku gajah, paku laut* (Malay); *sumo* (Wapi); *ftoi* (Weda); *bakutu, djoedjaroet, djudjarn, madjong utu, pekis rady, utta niwel, utta nuer* (unidentified languages) (Hill 1994a, Pant 1962, Schuster 1932, Bonta & Osborne 2007).

Typification: the original description of *C. rumphii* is based on 'Olus Calappoides' or 'Sajor calappa' of Rumphius, Herb. Amboinense., Lib. 1, Cap.XX excl. planta Celebica 1741. Most Rumphius specimens were lost in a ship wreck while en route to Europe (Stafleu & Cowan 1983). This leads to the conclusion that Miquel did not have either live plants or herbarium specimens available and that he relied strictly on the plates in Rumphius's work for his description. However, Hill (1994a) pointed out that one of the illustrations of Rumphius (1741) shows rather distinct lateral teeth on the megasporophyll. This does not entirely accord with other collections from the Moluccas and the larger teeth may be the artist's interpretation. De Laubenfels and Adema (1998) pointed out that recently collected material of *C. rumphii* cited by Hill (1994a) shows variation in the megasporophylls in that some have teeth while others do not. Besides the megasporophyll, other characters in these illustrations are inconsistent with collections from the type locality; specifically the overall shape of the megasporophyll lamina, the short spine on the megasporophyll tip, the clearly visible spines on the petiole and the fact that the seeds do not show any spongy layer. All of these characters could be the artist's interpretation, but it is more probable that the drawing was done from different plants, possibly even different species. Plate 22, overall much more resembles *C. scratchleyana*, a species that is found in the area and on neighboring Ceram. Both plates have been cited as the type (Hill 1994a; de Laubenfels, 1998). Miquel's description of *C. rumphii* initially encompassed Plates 22 and 23 of Rumphius. Later (1839) he placed his *C. celebica* (plates 20 and 21) into synonymy with *C. rumphii*. As Miquel's initial concept of *C. rumphii* was based on plates 22 and 23 these plates should serve as the type. However, recent studies of living specimens and herbarium material indicate that these plates (22, a female plant and 23, a male plant) represent two distinct species. Plate 23 was designated as the lectotype of *C. rumphii* by Lindstrom (2002) for two reasons. First, recently collected material of a male plant from Ambon (*Robinson 563*, Ambon, Wae) matches well with the illustration on Plate 23. Additionally, the current usage of the name *C. rumphii* is in agreement with the illustration on Plate 23 while Plate 22 matches *C. scratchleyana*. Choosing Plate 22 as the type would cause major and unnecessary nomenclatural instability while selecting Plate 23 as the type increases nomenclature stability in the genus. Based upon examination of recently collected material, (see specimens examined), *C. celebica* must correctly stay as a synonym of *C. rumphii*. De Laubenfels' (1998) recognition of *C. celebica* as a distinct taxon was evidently based upon the lack of spines on the petiole in the type illustration. This is correct in the type drawing but not consistent within several populations examined in Sulawesi.

Stems arborescent, to 3(–10) m tall, 11–20 cm diam. at narrowest point. *Leaves* bright green, highly glossy, 150–250 cm long, flat (not keeled) in section (opposing pinnae inserted at 180° on rachis), with 150–200 leaflets, with orange tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 35–60 cm long (20–30% of total leaf), glabrous, spinescent for 0–100% of length; basal leaflets not gradually reducing to spines, 190 mm long. *Median leaflets* simple, strongly discolorous, 220–320 mm long, 12–16 mm wide, inserted at 70–85° to rachis, decurrent for 5–8 mm, narrowed to 4.5–7 mm at base (to 35–50% of maximum width), 15–19 mm apart on rachis; section flat; margins slightly recurved; apex acute, not spinescent; midrib flat above, raised below. *Cataphylls* narrowly triangular, soft, shortly pilose. *Pollen cones* fusiform, yellow to brown (pale), 35–55 cm long, 10–15 cm in diameter; microsporophyll lamina firm, dorsiventrally thickened, apical spine rudimentary, sharply upturned, 2–5 mm long. *Megasporophylls* 18–32 cm long, white-tomentose or yellow-tomentose; ovules 2–6, glabrous; lamina lanceolate, 50–75 mm long, 25–35 mm wide, obscurely dentate; with c. 12 soft lateral spines 0–4 mm long, 0–2 mm wide; apical spine distinct from lateral spines, 10–25 mm long. *Seeds* flattened-ovoid, 45 mm long, 30 mm wide; sarcotesta orange-brown, not pruinose; 3–4 mm thick, fibrous layer absent; sclerotesta apically crested; spongy endotesta present. Fig. 4.

Historical notes: although first legitimately described in 1839 by Dutch botanist Miquel, the existence of a distinct Malesian taxon was first recognised by Roxburgh (1832: 747), on the basis of plants in cultivation in the Calcutta Botanic Gardens. He recognised that two taxa were present, treating one as *C. circinalis* and describing the other as a new species *C. sphaerica* Roxb. Roxburgh had, however, mistakenly applied the new name *C. sphaerica* to plants from India belonging to the *C. circinalis* alliance.

The distinct Malesian taxon he then treated under the name *C. circinalis*, although he had also mixed material of the two taxa under each description.

Miquel's *C. rumphii* (1839: 45) was based on part of Olus Calappoides of Rumphius (1741) and he was never clear on the specific limits of this taxon, at first separating material from Sulawesi as *C. celebica* (1839: 45), and later (1868: 232), combining the two. Miquel also separated material from Timor as *C. rumphii* var. *timorensis* (1841: 125), and from Java as *C. circinalis* var. *javana* (1842: 28). In addition, he at first recognised Roxburgh's *C. sphaerica* (1843: 693), apparently on the basis of Roxburgh's published account and without realising the confusion with *C. circinalis*. He later (1851: 32) correctly noted Roxburgh's confusion, and placed *C. sphaerica* in the synonymy of

C. circinalis, although later still (1868: 230), he again recognised *C. sphaerica* at specific rank. At the same time (1868: 232), he placed *C. celebica* and *C. circinalis* var. *javana* in *C. rumphii*, with no mention of *C. rumphii* var. *timorensis.*

Warburg (1900) also recognised the presence of a coastal taxon in New Guinea (including the Province of Papua, Indonesia), assigning it to *C. rumphii*. This taxon has also been assigned to *C. circinalis* (White 1923).

Distinguishing features: distinguished by the broad, falcate, hard, glossy leaflets with relatively broad bases, present but discontinuous laminar hypodermis, the relatively long and usually wholly spinescent petiole, the male sporophyll lacking a distinct terminal spine (Fig. 5.) and the narrowly triangular megasporophyll lamina with a slender apical spine (10–25 mm long) and reduced lateral spines. Adaxial mesophyll is usually continuous across the moderately broad and rounded midrib, but sometimes interrupted by the midrib in the east of the range. This may be due to genetic admixture of *C. bougainvilleana* from further to the east. The condition of reduced lateral spines also occurs in *C. edentata*, and related taxa from Philippines, Malaysia and the Indian Ocean. The latter taxa (not all treated herein) are, however, distinguished as a group by the lack of the apical crest on the seed.

Distribution and habitat: *Cycas rumphii* has been poorly understood in the past. Recent recognition of a number of related species has allowed clarification of its identity, and clear delineation of its distribution (Fig. 1). As now understood, *C. rumphii* has a distribution centred on the Moluccan island group (Maluku, or the Spice Islands) extending east into Indonesian Papua and a short way along the north coast of Papua New Guinea, and north to Sulawesi. In the west, it appears to extend to southern Borneo, north-eastern Java and Christmas Island.

C. rumphii appears to share the ecological preferences of several other taxa in this group, being largely a species of closed woodland or forest on more or less calcareous substrates in near-shore environments.

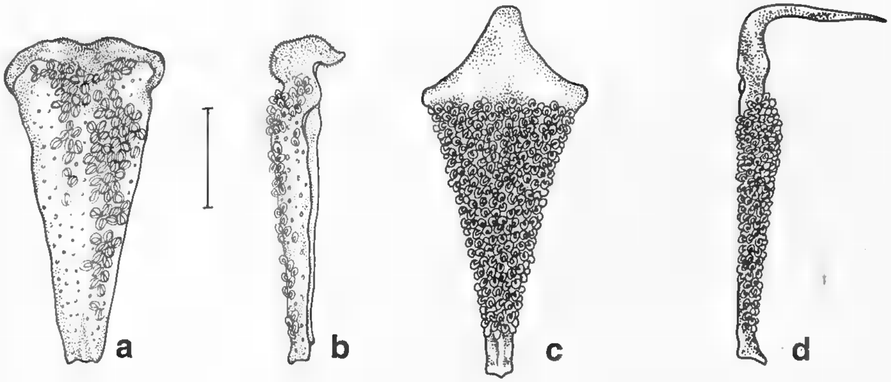

Fig 5. Comparison of male sporophylls. **a, b,** *Cycas rumphii*. **c, d,** *Cycas edentata* (a, b, from *NSW 714722 Claussen s.n.*, c, d, from *Hill 4630* by N. Oram). Scale bar = 1 cm.

Recognition of *C. rumphii* as a distinct species has been widely argued, with early discussion very ably summarised by Stapf (1916). Schuster (1932: 74) provided an essentially correct treatment of this species (with the exception of the varieties and subspecies, and the New Caledonian material cited), in contrast to his confused treatment of most other species. The name has been generally accepted subsequently, although misapplications of the name *C. circinalis* to this and related taxa continue (eg. Jones 1993, corrected in 2nd edition, Jones 2002).

Conservation status: the 1997 IUCN Red List of Threatened Plants lists *C. celebica* as R, although very little is known of this or in fact most occurrences in this region. Once abundant and widespread, this species occurred in coastal sites that have experienced severe pressures from population increase and development. This habitat is also coming under increasing pressure for aquaculture sites. Although probably not immediately threatened, it is potentially vulnerable in the longer term. Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003).

Selected specimens examined: AUSTRALIA: Western Australia: Christmas Island, Top of escarpment, Tom's Ridge, 1 km south of McPherson Point, near northwest point, *J. Claussen s.n & B. Claussen.*, 07 Mar 2005 (NSW *714734*); Just over the edge of the plateau escarpment, 500 m west of Runaway Cave, North East Point, *J. Claussen s.n.* & *B. Claussen*, 24 Feb 2005 (NSW *714722*); On the edge of the plateau escarpment, c.1.34 km WNW of Wright Point, East Coast, *J. Claussen s.n.* & *B. Claussen*, 18 Feb 2005 (NSW *714713*). **Northern Territory:** Ashmore Reef. 12° 15'S 123° 00'E. Seeds found washed up on beach, probably from Indonesia, *Leach s.n.*, Oct 1996 (NSW).

INDONESIA: [No locality given], *Noblick s.n.* (FTG); [No locality given], *Anon.*, 13 Nov 1993 (NSW). **Jawa Timur:** Srigontjo Sen Z. van Malang aan de Zuidree, strand, *Backer 3825*, 10 Jun 1922 (BO); Kangaean, Soebi, 1.5 m, *Backer 20371*, 12 Apr 1920 (BO); Kangaean P. Mamboerit 1 m, *Backer 27279*, 19 Mar 1919 (BO); Sepandjang [c. 8° 10' S 112° 40' E], *Backer 28875*, 21 Apr 1919 (BO); Zo. Saboentern 0.5 m, *Backer 29746*, 9 May 1919 (BO); Res Soeraharta [Surakarta 7° 32' S 110° 50' E], zuidkust bij Paranggoepita c 20 m, *Burger 5629*, 31 Aug 1922 (BO). **Kalimantan Barat:** Karimata Arch., Poelau Pelapis Giangbalai, *Mondi 136*, 22 Mar 1931 (L, BO). **Maluku:** Ambon, Wae [Waa], *Robinson 563*, 29 Nov 1913 ([M], A, BM, BO, K, L, NSW, NY, P); Wae, Amboina *[Ambon]*, *Robinson s.n.*, Jul 1913 (NSW). Aru, Pulau Wokam, Dosinamaloe, *Buwalda 4971*, 16 May 1938 (BO, BRI); *Lauterbach 259* (BO); Kobroor, *Durbaum s.n.*, Aug 1995 (NSW); *"Amboina"*, herb. Maire, *leg. ign.* (P); "Moluccas", *Brogniart* (BM). Buru, NW Wae Dana River N of Bara, 100-300 m, old river bed, limestone, *LBN-L 5269, field no 208*, 25 Nov 1984 (L). Halmahera, Pajehi [Payahe] Road, Weda District, *de Haan 1798*, 2 Nov 1950 (A, BO, K, L, NSW, NY, SING); Halmahera, cult. in kao town, *Lindstrom 151* (NSW, UBC); road between Doro and Pediwang, on coral rock near sea, *Lindstrom 153, 154* (NSW, UBC), *Lindstrom* 155 (UBC); on coral soil along stream near sea, *Lindstrom 156-7* (NSW, UBC). Obi, *Atasrip 60*, 1899 (BO, L). Ternate, Sango, *Beguin 1080*, 1 Nov 1920 (BO); Takome, base of Mt Gamalama less than 50 m from sea, *Lindstrom 158* (NSW, UBC); Sulamedaha, base of Mt Gamalama about 100 m from sea, *Lindstrom 159* (NSW, UBC). Tidore, road between Sidangoli and Tobelo, between km 6 and 7, near roadside, *Lindstrom 148* (NSW, UBC); Cult., in Kao town, *Lindstrom 152* (NSW, UBC); near Bubaneigo, along road, *Lindstrom 150* (NSW, UBC). **Papua:** Diak [? Biak] Bosnik, Schouten Is., *Gibbs 6278*, Dec 1914 (K, BM). **Sulawesi Utara:** Menado, Loewoek, Tobelombang, *Eyma 3727*, 13-16 Sep 1938 (L, BO); Minahassa, Menado, strand, Pandano, *Koorders & Seepit 2868*, 19 Feb 1895 (BO); *Koorders 16646* (L ex BO); "specimen from Forster", *Koorders 16647B* (BO); *Koorders 16648* (L, BO); *Koorders 16648B*, 19 Feb 1895 (B, K, L); N of Manado, Wori town, near beach, *Lindstrom 145* (NSW, UBC); **Sulawesi Tengah:** N central, on coast SW of Donggala, *Meijer 10071*, 11 May 1975 (BO); *Teijsmann s.n.*, 1859-60 (L). **Sulawesi Selatan**: Saleier group[?Salayar]: 2nd

Saleier, zandige kust, *van Leeuwin 1881*, 13-16 Sep 1938 (BO); Saleier groep, Eil Kalao [Kalao Is], strand, *van Leeuwin 1853*, 2 May 1923 (BO); Tapalang, *Noerkas 481*, 4 Aug 1912 (K, L, BO). **West Papua:** Raja Ampat, Marchesa Bay Amdoei on N bank of bay, *van Royen 3300*, 2 Apr 1954 (L, BRI, CANB, K, P).

PAPUA NEW GUINEA: voyage of HMS Sulphur, *Barclay 3540*, Jul-Aug 1840 (BM, L); **West Sepik:** near Yakoi village, 1 mile [1.6 km] W of Aitape, Aitape Subdistrict, *Darbyshire and Hoogland 7855*, 3 June 1961 (CANB, BM, BRI, L, LAE); Yako village, Vanimo Subdistrict, *Streimann LAE53828*, 2 Dec. 1971 (LAE, BRI, K, L, CANB).

Cult. Royal Botanic Gardens, Sydney, *Harwood s.n.*, May 1913 (NSW); *Boorman s.n.*, 1902 (NSW); *Boorman s.n.*, Jun 1915 (NSW); seed from Durbaum 1995, *s.n.* (NSW).

7. *Cycas edentata* de Laub., in de Laubenfels & Adema, Blumea 43(2): 372 (1998).

Type: Philippines, Sulu Archipelago, Mt Cabucan, *Kondo & Edaño 38877*, Jan-Feb 1957 (holo L, iso A, BM).

Cycas litoralis K.D. Hill, Brittonia 51(1): 70, fig. 11 (1999).
Type: Thailand. Ao Manao Naol, Narathiwat, *K.D. Hill 4627 & Poonsak Vatcharakorn*, 20 Apr 1994 (holo NSW, iso BKF, K, L, PE)

Cycas circinalis subsp. *riuminiana* var. *curranii* forma *maritima* J. Schust., Pflanzenr. 99: 69 (1932).
Lectotype (here designated): Philippines, Calusa Island, 29 July 1912, *Fenix 15660* (lecto K; isolecto L).

Literature: Lemaire (1864 as *C. circinalis* and *C. rumphii*), Kurz (1877 as *C. rumphii*), Foxworthy (1911 as *C. circinalis*), Merrill (1912 as *C. circinalis*), Merrill (1917 as *C. rumphii*), Merrill (1918 as *C. circinalis*), Merrill (1921 as *C. circinalis*), Merrill (1923 as *C. rumphii*), Backer (1925 as *C. rumphii* p.p.), Ridley (1925 as *C. rumphii*), Leandri (1931 as *C. rumphii*), Ochse (1931 as *C. rumphii* p.p.), Schuster (1932 as *C. rumphii* p.p.), Kanehira (1938 as *C. rumphii* p.p.), Ho and Duong (1960 as *C. rumphii*), Suvatabandhu (1961 as *C. rumphii*), Backer and Bakhuizen van den Brink (1963 as *C. rumphii* p.p.), Smitinand (1971 as *C. rumphii*), Smitinand (1972 as *C. rumphii*), Zamora and Co (1979 as *C. circinalis*), Amoroso (1986 as *C. rumphii*), Hill and Yang (1999 as *C. litoralis*).

Illustrations: Ridley (1925), Schuster (1932 as *C. rumphii* p.p.), Smitinand (1971), Cheng et al. (1975 as *C. rumphii*), Amoroso (1986 as *C. rumphii*), de Laubenfels and Adema (1998), Hill & Yang (1999 as *C. litoralis*)

Etymology: from the Latin *dentata*, toothed, with the Latin prefix *e*-, without, in reference to the megasporophyll apices.

Vernacular: *kwale pahang* (woods on sea shore)(Malay); *prong thale* (sea cycad) (Thai), *sauang, sawang* (Ilocano); *bait, bayit, pitógo* (preferred to *potago, patubo, pitugo* or *bitogo*) (Tagalog); *oliba, oliva* (preferred) (Spanish); *uliba, uliva*; (unidentified language) (Hill & Vatcharakorn 1998, Ridley 1893, Amoroso 1986, Schuster 1932, Zamora & Co 1986, Bonta & Osborne 2007).

Stems arborescent, to 10 m tall, to 20 cm diam. at narrowest point. *Leaves* bright to deep green, highly glossy, 130–230 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis), with 100–200 leaflets, tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets; petiole 30–90 cm long (20–50% of total leaf), glabrous, spinescent for 5–100% of length; basal leaflets not gradually reducing to spines, 120–280 mm long. *Median leaflets* simple, strongly discolorous, 220–370 mm long, 11–19 mm wide, inserted at 45–80° to rachis, decurrent for 5–13 mm, narrowed to 5–8 mm at base (to 35–50% of maximum width), 12–35 mm apart on rachis; section flat; margins slightly recurved, not undulate; apex acute, not spinescent; midrib flat or raised above, raised below, wide. *Cataphylls* narrowly triangular, soft, pilose, 40–70 mm long. *Pollen cones* narrowly ovoid or fusiform, orange, 35–60 cm long, 11–17 cm diam; microsporophyll lamina firm, not dorsiventrally thickened, 35–44 mm long, 12–23 mm wide, fertile zone 30–35 mm long, sterile apex 5–6 mm long,; level to slightly deflexed; apical spine prominent, sharply upturned, 9–24 mm long. *Megasporophylls* 24–50 cm long, white-, yellow-tomentose or brown-tomentose, tomentum persistent; ovules 2–8, glabrous; lamina lanceolate, 43–120 mm long, 20–40 mm wide, lateral spines short or indistinct; apical spine distinct from lateral spines, 14–40 mm long, 4–12 mm wide at base. *Seeds* flattened-ovoid, 45–66 mm long, 35–50 mm wide; sarcotesta orange-brown, not pruinose, 3–5 mm thick; fibrous layer absent; sclerotesta smooth; spongy endotesta present. Fig. 4.

Historical notes: described by de Laubenfels and Adema in 1998.This taxon has been included in *C. rumphii* by numerous authors, starting with Kurtz (1877), with the exception of Foxworthy (1911), Merrill (1912, 1918, 1921) as *C. circinalis,* Schuster in 1932 described it as *C. circinalis* subsp. *riuminiana* var. *curranii* forma *maritima.* Hill recognised this as a distict taxon in 1995 (Hill 1998) and formally described the taxon as *C. litoralis* in April 1999. De Laubenfels had already described this taxon as *C. edentata,* published in 1998 but with a confused circumscription that included *C. glauca, C. rumphii* and others.

Distinguishing features: the non-pectinate megasporophyll (Fig. 4), the very glossy leaves and the large seed with spongy endotesta place this species unmistakably in the *C. rumphii* group. Within that group, it is distinguished from *C. rumphii* and all related species occurring to the south and east by the distinct, long, stout spines terminating the microsporophylls (Fig. 5.). *C. thouarsii* from the south-western Indian Ocean shares this microsporophyll character, but differs in having narrower leaflets that are distinctly glaucous when developing. *C. zeylanica* (J. Schust.) A.Lindstr. & K.D.Hill from Sri Lanka and The Andamans is characterised by longer, narrower and more attenuate megasporophylls, more widely spaced leaflets and more abundant, longer and distinctly pungent cataphylls with a more rufous tomentum.

Distribution and habitat: *Cycas edentata* occurs in south Vietnam, southern Burma and southern Thailand, extending south into peninsular Malaysia, Sumatra, Java and northern Borneo but apparently not elsewhere in Indonesia (Fig. 1). Once common around the coast of southern Thailand, but now removed from many sites. It also occurs in the western and central parts of the Philippines. This species occurs only along shorelines, in full sun to moderate shade in often dry littoral scrubs on beach sand or rocky headlands, often in very shallow soil and apparently over both granite and limestone substrates.

Conservation status: once abundant and widespread, this species occurred in coastal sites that have experienced severe pressures from population increase and development. This habitat is also coming under increasing pressure for aquaculture sites. Although probably not immediately threatened, it is potentially vulnerable in the longer term. Recommended Ver 3.1:IUCN(2001) status would be **NT** for Indonesia.

Selected specimens examined: INDONESIA: Bali: Gilimanuk, *Forman 176*, 9 Jun 1956 (BO, L). **Jawa Barat:** Oedjoeng Genteng [Ujunggenteng], *Backer 17409*, 25 Nov 1914 (BO); Pulau Panaitan, Tg Manik, beach, *Borssum Waalkes 523*, 13 Sep 1951 (L, BO); Pulau Handenberm [handeuleum], Uejong Kulor[Ujungkulon], W Java, *Wyatt-Smith KEP 93185*, 20 Dec 1958 (KEP, K); Cidaun distr., near Kabun Kopi village, on sand dune less than 50 m from sea, *Lindstrom 166,170* (NSW, UBC); cult in village, coll. nearby, *Lindstrom 171* (NSW, UBC); Pulau Handeulum, Udjong Kulou[n], W. java seashore, *Wyatt-Smith KEP 93185*, 20 Dec 1958 (KEP, K); Res W Preangar, Zuidkust, strand Oedjoeng Genteng bij pasanggrahan 1–2 m, *van Steenis 11286*, 29 Jun 1939 (BO). **Jawa Tengah:** Res Zuidkediri, Baai van Damas bij Prigi, 1 m, *Backer 11956*, 17 Feb 1914 (BO); Res. Preangar, Tjialin a/d Tjitarik, (by Tjisalak, Paroengkoeda) Res Oreabgar, 500 m, *Bakhuizen v.d. Brink 5086*, 21 Dec 1920 (BO); Wirosari dist, Cult Res Semarang Afd. Grobogan Ab Tambiredjo, *Beaumee s.n.*, 25 Sep 1916 (BO); Pasveroean, *Buysman 16*, 14 Aug 1907 (BM); Java Tengah, *Horsfeld 80* (BM, L); Banjumas, Nusa Kambangan Is., SW part betw. Solek Babakan and S. Djeroeh, *Kostermans & van Woerden 188*, 23 Nov 1938 (BO, L); Jimghun, *leg. ign.* (L); Zuidelph deil van Paroela, *leg. ign. 3825*, 1912 (BO); Prov. Banjoemas, Noesa Kambangan, *Koorders 20106 B*, 10 Jun 1895 (L, BO); Noesa Kambangan, *Barbey s.n.*, 23 Nov 1921 (L). **Jawa Timur:** bij Kamalbaai, Nusa Barung [c. 8° 28' S 113° 21' E], vern Soemberdjambe, *Abdoelmachna 202*, 12 Mar 1950 (BO); Res Bondowoa, Radjagwesiebaai, Barringtonia Bosch 0–3 m, *Clason s.n.*, 6 Sep 1936 (BO); Res Mondooman, Radjegweribaai, *Clason s.n.*, 6 Sep 1936 (BO); Res Besoeki, Noeesa Baroeng, Zuid Kandangan, *Hoogerwerf 6*, 4 Jul 1939 (BO); Besoeki [8° 13' S 111° 46' E], Distr. Poeger afd. Djember, Boschterrein Poeger – Watangan [c.8° 05' S 112° 55' E], *Koorders 12727 B*, 10 Dec 1892 (L, BO). **Sumatra:Unknown Province:** *Seemann 2329* (LE). **Bengkulu:** Enggano, Kiorjoh, *Lutjeharms 4691*, 13 Jun 1936 (BO, L, BRI, K, NY, P); Sumatra, *Korthals 901324-28* (L); Batrie Eilanden, *Raap 9*, 3 Sep 1896 (BO, L); Benghoelen, Throei, *van Steenis 3162*, 25 Oct 1929 (L, BO). **Lampung:** Eile Krakatoa, *Backer 50*, 1910 (L); *Backer 1918*, Apr 1906 (B, K); Lang Eiland, Krakatau group, *Backer 34865*, 6 May 1908 (BO, L); Krakatoa, Lampangsche distr, *Backer 34866*, Apr 1906 (BO); Krakatau, *Valeton s.n.*, 1 Mar 1905 (L); N Zirarte Hoeb, *van Leeuwin 3721*, 27 Apr 1919 (BO); N Zurarte Hoeb, *van Leeuwin 3830*, 6 Oct 1929 (BO). **Riau:** Anamba Islands, Padang near Leting Jemaya, *Henderson SF 20338*, 11 Apr 1928 (BO, K). **Sumatra Utara:** Cult., Sibolangit Bot. Gard., N. Sumatra "common in lowlands", *Lorzing 12206*, 20 Oct 1927 (BO, K); Medan, N. Sumatra, *Lorzing 16881*, 1934 (BO, L).

MALAYSIA: Johore: Tg Penawar, coast, *Cockburn FRI 7565*, 8 Feb 1968 (KEP, K); Pulau Tioman, *Lee s.n.*, 28 May 1974 (BKF); Pulau Tinggi, rocky coast, *Ng FRI 5034*, 16 Apr 1967 (KEP); Mersing, Pulau Lima, rocky coast, *Ng FRI 5062*, 17 Apr 1967 (KEP); Desaru, Tg Penawar, *Ng & Yap FRI 27197*, 25 Aug 1978 (KEP); Pahang Tanjong Gelang, beach forest, *Putz FRI 023617*, 27 Apr 1975 (KEP); SE, Padang Mulut, *Shah & Shukor MS 2480*, 19 Sep 1971 (BKF, BRI); Desaru complex, beach forest, *Yap FRI 27196*, 23 Aug 1978 (KEP). **Langkawi:** P. Dayang Bunting, *Henderson SING 29160*, 27 Nov 1934 (K). **Malacca:** cult, *Maingay 1506*, 1867–68 (K). **Pahang:** Distr. Rompin, near Bevar village, road to Pekan, near edge of beach forest, *Kochummans & Yong KEP 9498*, 30 Jul 1962 (KEP); Kwala Pahan, *Ridley s.n.*, May 1890 (BM). **Perak:** *Ridley 7143*, Mar 1896 (K). **Sabah:** Membakut distr., HS Binsulok, *Amin SAN 126098*, 19 Jan 1991 (KEP); Kudat distr., Pulau Balembangan, midwest just E of Tg Penbatu, *BCS, EFA, LM et al SAN 86813*, 12 Apr 1977 (KEP, L); Mt Silamarea, Lahad Datu distr., *Chai SAN 29392*, 20 Apr 1962 (K ex SAN); Jesselton, *Clemens 11277*, Dec 1916 (B, K); Kota Kinabalu, Sapi Is 200 m W of Gaya Is, *Davidson 1120*, 9 Mar 1970 (L); Pulau Bulang, *leg. ign. 15699*, Apr 1911 (K). **Sarawak:** Telok Limau, Bako NP, sandy sea shore, *Ashton S 17927*, 5 Jun 1963 (K); Santubong, 1st div., *Chai et al. S 38561*, 17 May 1980 (KEP, K, L); Kapit, upper Rejang River, *J. & M.S. Clemens 21175*, 1929 (B, K, NY); Usatian Bay nr Keppel, *Gibbs 4337*, 1910 (BM); Datu PF, 1st div., *Lee S 41866*, 16 Apr 1977 (KEP, K, L); Kuching, Setapok FR, in peaty swamp forest near coast, c 100m, vern Paku laut, *Murthy 9576*, 1957 (K, L). **Terengganu:** Kemaman, Rasau Kerteh Ulu Chukai F.R., Hillside forest, *Meijer & F.C. Yong KEP 94932*, 2 Jun 1962 (K); Pulau Redang, Pasir Mah Kepit, *Saw FRI 36473*, 4 Feb 1989 (KEP).

PHILIPPINES: Balabac: Bancalan Is, *Weber s.n.*, Jul 1916 (A). **Basilan:** *Hutchinson FB 3441*, 10 Dec 1905 (K); *Klemme FB 15219*, Aug 1910 (K, L).**Cebu:** Lapu Lapu City, Olango Island, *Madulid et al. PPI 7623*, 20 Mar 1993 (BO). **Masbate:** Hamoraon Island, *Kondo & Edano PNH 36862*, 30 Mar 1957 (L). **Mindanao:** Davao Oriental, Mati district, Mayo Bay, cult. at the House of F.G.R.Dahican (Mayor), Planted 1960's, said to come from nearby now destroyed seaside, *Lindstrom 06/001, 06/002*, 29 Feb 2006 (NSW); Prov. Davao, Caldera, *Wilkes exped. s.n.*, 1832–1842 (GRAY); Santa Cruz, *Williams 2890*, 17 Jun 1905 (NY); between Digas and Santa Cruz, *Williams 3058*, 29 Jun 1905 (GRAY, K, NY). **Mindoro:** Bongabon and Pinamalayan, *Maliwanag 253*, 5 Feb–5 Apr 1941 (A). **Negros**: Negros Oriental, Dumaguete district, Secondary seriously destroyed seaside forest, *Lindstrom 06/005*, 3 Mar 2006 (NSW). **Palawan:** Culion, Alava Island, Halsey Harbour, *Fernando E 1609, 1610*, 22 Jun 2001 (LBC); cult. Puerto Princessa city, coll. from coastal forest near San Vicente, *Fernando E 1616*, 26 Jun 2001 (LBC). **Panay:** Iloilo, fide Amoroso 1986 (no voucher). **Polillo:** fide Amoroso 1986 (no voucher).

SINGAPORE: Changi, *Ridley 4408*, 1892 (BM, K); *Ridley s.n.*, 1893 (BM, K); Kampong Pesek, Pulau Pesek, *Sinclair 5842*, 6 Jun 1949 (E).

THAILAND: "Pulau Mohea, WC Siam" vern. Bogak, *Field 2690*, 2 Feb 19[??] (K). **Chumphon:** collected from Chumphon, cult. Nong Nooch Garden, *Hill 4644*, 30 Apr 1994 (NSW); Ban Thung Maha, *Kerr 11355, 11355A*, 10 Jan 1927 (BM, K); Ko Tao, *Kerr 12768*, 16 Apr 1927 (BM, K); *Kerr 16087*, 25 Sep 1928 (BM, K). **Narathiwat:** Narathiwat, *Charoenphol, Larsen & Warncke 4064*, 20 Oct 1970 (BKF, K, P); Ao Manao Nowl, Narathiwat, *Hill 4627*, 20 Apr 1994 (NSW); near Narathiwat, *Yang 632, Tang & Vatcharakorn*, 27 Jan 1995 (FTG). **Phang Nga:** Takuapa, *Abbe, Smitinand & Rollet 9684*, 19 Mar 1960 (NY); Ko Ngai, *Hansen & Smitinand 12242*, 11 Feb 1966 (BKF, E, K); Ko Kaw Khao, *Larsen, Larsen, Neilsen & Santisuk 30984*, 15 Jul 1972 (BKF, P); **Phu Ket:** cult. Ban Na Si Thon, collected from Phuket, *Hill 4630*, 21 Apr 1994 (NSW); cult. Nong Nooch Garden, *Yang 659, Tang & Vatcharakorn*, 30 Jan 1995 (FTG). **Satun:** Adang, beach, *Congdon 101*, 23 Oct 1979 (A); Tarutas, across Malacca Ck, *Congdon 42*, 17 Oct 1979 (A). **Trang:** "Pulau Mohea, WC Siam", vern. Bogak, *Field 2690*, 2 Feb 19[??] (K); island off coast near Trang, *Robinson s.n.*, Dec 1916 (K). **Trat:** Ko Chang, *Kerr 16569*, 10 Jan 1929 (BM, K); Ko Kut, *Smitinand 5725*, 6 Apr 1959 (BKF).

VIETNAM: Kien Giang: near beach, west part of Phu Quoc island, *leg. ign.* (Botany Dept Univ Ho Chi Minh).

Cult.: hort Bogor, Indonesia, *Stolk 149* (BO, L).

8. *Cycas sundaica* Miq. ex A.Lindstr. & K.D.Hill, **sp. nov.**

A Cycade rumphii et C. edentata megasporophyllis spinis lateralibus prominentibus, foliolis plerumque angustioribus differt.

Type: Flores, Ngada province, foot of Volcano Inerie, along the Eku Ture river, mear Bidhu village, 326 m ASL, *Lindstrom 255*, 29 Apr 2000 (holotype: BO, iso: UBC).

[*Cycas sundaica* Miq. in J.Schust., Pflanzenr. 99: 74 (1932), nom. nud. in synonymy]

Etymology: from the habitat, entirely within the Sunda Island group.

Stems arborescent, to 5 m. tall, 20–35 cm. diam. at narrowest point. *Leaves* bright green or deep green, 120–275 cm long, flat in section (opposing leaflets inserted at 180° on rachis), with 75–114 leaflets, with orange to greyish tomentum shedding as leaf expands; rachis usually terminated by a spine to 13 mm long; petiole 30–67 cm long (20–40% of total leaf), spinescent for 10–100% of length; basal leaflets not gradually reducing to spines. *Median leaflets* simple, strongly discolorous, 230–340 mm long, 9–15 mm wide, narrowed to 3–5 mm at base (25–50% of maximum width), 13–23 mm apart on rachis; section flat; margins slightly recurved; apex spinescent; midrib flat above, raised below. *Cataphylls* linear, pungent, to 10 cm long. *Pollen cones* ovoid, c. 16–30 cm long, 9–15 cm wide; microsporophylls firm, not dorsiventrally thickened, 30–55 mm long, 15–29 mm wide, fertile zone 22–45 mm long, sterile apex 6–10 mm long, apical spine abruptly raised, 12–20 mm long. *Megasporophylls* 30–42 cm long, tomentum persistent; ovules 2–8, glabrous; lamina lanceolate, 30–80 mm long, 20–43 mm wide, shallowly pectinate or regularly dentate, with 4–30 pungent lateral spines 1–12 mm long, 1–1.5 mm

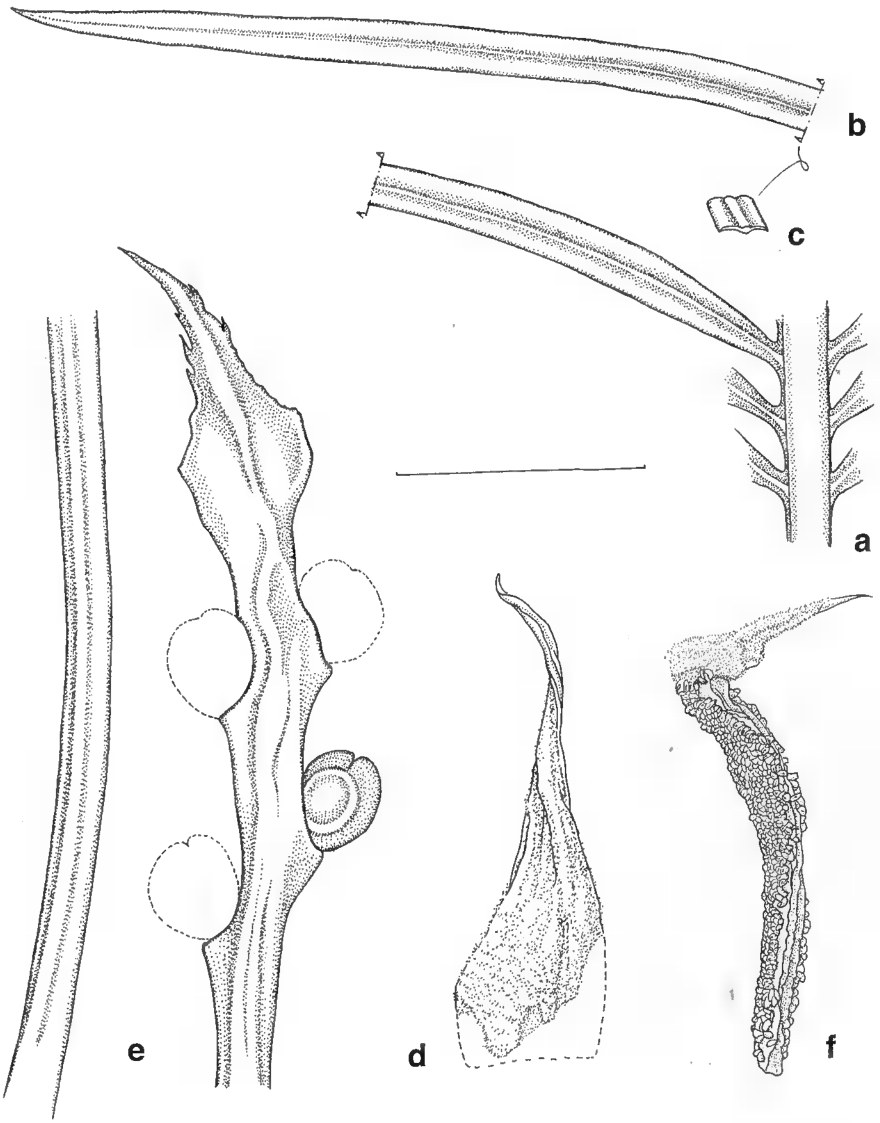

Fig. 6. *Cycas sundaica*. **a, b,** part of leaf. **c,** cross-section of leaflet. **d,** cataphyll. **e,** female sporophyll. **f,** male sporophyll (a, b, c, d, e from *Lindstrom 255,* f from *Lindstrom 258.* d, f, by C. Wardrop). Scale bar: a–e = 5 cm; f = 2.5 cm.

wide; apical spine distinct from lateral spines, 30–50 cm long, 3–7 mm wide at base. *Seeds* ovoid, 45–55 mm long, 35–45 cm wide, sarcotesta orange, c. 8 mm thick, fibrous layer absent; sclerotesta smooth; spongy endotesta present. Fig. 6.

Historical Notes: *C. sundaica* was a name used by Miquel on a herbarium sheet in Utrecht. Schuster (1932) listed Miquel's name in synonomy under *C. rumphii,* although Miquel never published the name.

Distinguishing features: the distinct lateral spines on the megasporophyll lamina distinguish this taxon from the nearby and related *C. rumphii* and *C. edentata*. Leaflets are also on average narrower.

Distribution and habitat: Nusa Tenggara Timur only, on Sumbawa, Komodo, Rinca, and Flores, east to Alor, in near-coastal and lowland forests (Fig. 1).

Conservation status: locally abundant and known to occur in reserved areas set aside for the conservation of the Komodo Dragon, this species is not considered to be at immediate risk. Recommended Ver 3.1:IUCN(2001) status would be **LC.**

Selected specimens examined: INDONESIA: Nusa Tenggara Timur: Alor, Altimelang, 750 m, *du Bois 74*, 26 Jan 1939 (BO); Distr. Krei, Moro-Gendok, 300 m, *Jaag 667*, 7 May 1938 (BM); Taramana, Pisigomo 700 m, *Jaag 893*, 11 May 1938 (BM); Flores, Endeh, 20 m, *Rensch 982*, 9 Jun 1927 (BO); W. Flores, E. Manggarae, Pota, 200 m, *Schmutz 4712*, Dec 1980 (L); Ngada province, foot of Volcano Inerie, along the Eku Ture river, mear Bidhu village, *Lindstrom, 256, 259,* 29 Apr 2000 (BO, UBC).

Subsection Endemicae Schuster (1932: 65).

Lectotype (here designated): *Cycas media* R.Br. Prodr. 1: 348 (1810). Type: Australia, "New Holland, North Coast", *R. Brown s.n.* (holo BM; iso K).

No type species was designated. Schuster included three species in this section, which he defined only on the pungent-acuminate pinnae and the relatively small and slender megasporophylls. *Cycas media* R.Br. is chosen as lectotype of the subsection, being the most well-known and earliest-described of the three species, and also adequately satisfying Schuster's definition.

This subsection is distinguished by the relatively flattened microsporophylls with a short and sharply upturned apical spine, the lack of spongy tissue within the seed, and the lack of a fibrous layer in the sarcotesta. Pinnae are often pungent-acuminate, as stated by Schuster, but not in all species, and often no more so than in other groups. Eight series are recognised (Hill 1995b), six of them endemic in Australia, and two occurring in Australia and New Guinea. About 26 species are endemic in Australia, two endemic in Papua New Guinea, one species ocurring in Papua New Guinea and Irian Jaya, and one on Timor and Sumbawa.

9. *Cycas glauca* hort. ex Miq., Comm. Phytog.: 127 (1840–1841), non Link, Enum. Hort. Berol. Alt. (1821–22), nom. nud., nec Sweet, Hort. Brit. ed. 3: 627 (1839), nom. nud. *Cycas circinalis* forma *glauca* (Miq.) J. Schust., Pflanzenr. 99: 66 (1932).

Lectotype (here designated): Hort. Roterodam. (lecto U). This sheet most closely matches the basally restricted leaflets later described by Miquel (1868).

Cycas rumphii var. *timorensis* Miq., Comm. Phytolog.: 125–126 (1840–1841).
Type: Indonesia, Timor, ex Herb. Mus. Paris (holo L; iso LE, U).

Literature: Miquel (1842, 1843, 1861, 1868,), Lemaire (1864), De Candolle (1868), Regel (1876a, 1876b), Hill (1995a), Hill (1998), de Laubenfels and Adema (1998).

Etymology: from the Greek, *glaucus*, with a bluish waxy bloom, in reference to the bluish glaucous leaves.

Vernacular: *fay* (Amarassi dialect, West Timor).

Stems arborescent, to 3 m tall, 22–35 cm diam. at narrowest point, normally unbranched but occasionally branching 2–4 times at the apex. *Leaves* dark green, semi glossy, with a distinct glaucous blue cast, 174–220 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis), with 69–118 pinnae, tomentum often present even on mature leaves; petiole 42–58 cm long (20–40% of total length), covered in short orange tomentum, glaucous, spinescent for 20–100 % of its length. *Median leaflets* simple, glabrous, moderately discolorous, 15–30 cm long, 12–16 mm wide, narrowed to 0.2–0.5 cm at base (25–35% of total width), 5–14 mm apart on rachis, section flat, margins recurved, midrib slightly raised above, strongly raised below. *Cataphylls* narrow, elongated, soft, 3–4 cm long. *Pollen cones* c. 49 cm long, c. 10 cm wide, brownish, peduncle 8 cm long; microsporophyll 38–40 mm long, 18–20 mm wide, fertile zone 28–30 mm long, sterile apex c. 10 mm long, apical spine to 20 mm, raised. *Megasporophylls* 30–43 cm long, with persistent orange-brown tomentum; ovules 4–7, glabrous; lamina 25–40 mm long, 23–35 mm wide, shortly pectinate or with rudimentary spines; apical spine distinctfrom lateral spines, 20–40 mm long, 2–5 mm wide. *Seeds* flattened, 4–5 cm long, to 3 cm wide, sarcotesta yellow, ripening to dark brown red, strongly pruinose; fibrous layer absent, sclerotesta weakly ornamented; spongy layer absent. Fig. 7.

Historical notes: described by Miquel in 1840-41 from cultivated material in European collections as *C. glauca*. He also described *C. rumphii* var. *timorensis* in the same publication from a herbarium specimen in the Paris museum. Miquel in 1861 listed *C. glauca* under '*species incertae*' and in 1868 under '*nondum satis certae*' (not yet sufficiently certain). Lemaire in 1864 followed Miquel listing *C. glauca* under doubtful species. De Candolle (1868) listed *C. glauca* under '*species minus notae*' and Regel (1876) treated it as *C. glauca*. Schuster (1932) regarded *C. glauca* as a variety of *C. circinalis*, without really understanding the nature of *C. glauca*.

The types of *Cycas glauca* and *C. rumphii* var. *timorensis* consist solely of sterile leaves, making it extremely hard to relate it to any previously described species. Hill (1995a) first placed *C. glauca* into synonymy with *C. rumphii* but later (Hill 1998) placed the taxon into synonymy with *C. thouarsii*. De Laubenfels (1998) unaware of the type in Utrecht, regarded *C. glauca* as a nomen nudum but placed *C. glauca* into synonymy with *C. rumphii* and *C. rumphii* var. *timorensis* into the synonymy of his newly described *C. edentata*. More recent fieldwork conducted in Indonesia as part of an ongoing study into the systematics of the genus *Cycas* has shown *C. glauca* to be a distinct taxon unrelated to the *C. rumphii* group, widespread and locally abundant on the islands of Sumba and Timor.

Distinguishing characters: *Cycas glauca* is related to the Australian species, probably nearest to *C. silvestris* on the basis of leaflet width but differs in the distinct glaucous blue cast on the emerging leaves. It has a superficial resemblance with and could be confused with *C. thouarsii* (Indian Ocean) due to the bluish cast on the leaves, but differs in having wider pinnae and smaller seeds lacking a spongy layer.

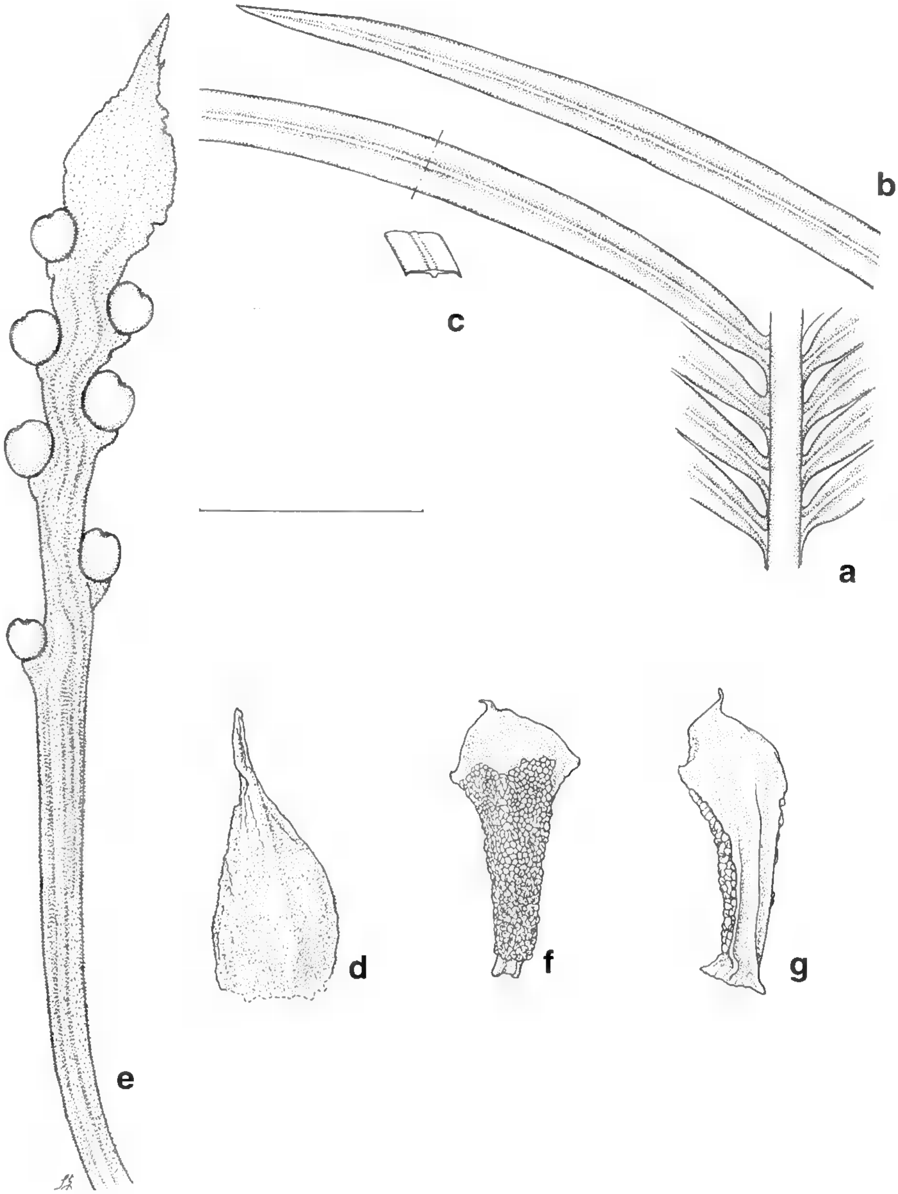

Fig. 7. *Cycas glauca*. **a, b,** part of leaf. **c,** cross-section of leaflet. **d,** cataphyll. **e,** female sporophyll. **f, g,** male sporophyll (a, b, c, d, e from *Lindstrom 274*. f, g from digital image (NSW) from Lindstrom, cult. Nong Nooch Botanic Gardens. d, f, g by C. Wardrop). Scale bar: a–e = 5 cm; f, g = 2.5 cm

Distribution and Habitat: *Cycas glauca* is apparently endemic to the islands of Timor and Sumba (Fig.1). Populations occur in closed evergreen forest, inland, often near streams. Populations also persist in disturbed areas.

Conservation Status: *Cycas glauca* is apparently quite widespread and locally abundant on both Sumba and Timor. It is unknown if there are any populations within protected areas. The present political unrest in Indonesia and Timor in particular, give cause for concern, as effective protective measures would be difficult to implement. Recommended Ver 3.1:IUCN(2001) status would be **VU.**

Selected specimens examined: INDONESIA: Nusa Tenggara Timur: Sumba: Exped. Soemba [*Sumba*], Djore, [Iboet] *237*, 11 Apr 1925 (BO, B, L); **Sumba Timur:** near Paimburu village, 274 m ASL, in sparse open evergreen forest, seasonally dry, clay soil, *Lindstrom 267, 268*, 4 May 2000 (BO, UBC); **Sumba Barat**: northern part, near Tana Righu village, *Lindstrom 273*, 6 May 2000 (BO, UBC); **Cult.** Waingapu town (Sumba Timur), *Lindstrom 274*, 6 May 2000 (BO, UBC). **Timur Barat:** 'Kabupaten Kupang, Amarassi prov.' near Oekabiti village, in closed evergreen forest *Lindstrom 245*, 25 Mar 2000 (BO, UBC); East Amarassi prov. near Baun village, 415 m ASL, *Lindstrom 246*, 25 Mar 2000 (BO, UBC).

TIMOR: *Leschenault s.n.* (P); *ex herb Moricand*, 1827 (P, G).

10. *Cycas papuana* F.Muell., Descr. Notes Papuan Pl. 1,4: 71–72 (1876). *Cycas circinalis* subsp. *papuana* (F.Muell.) J. Schust., Pflanzenr. 99: 70 (1932). *Cycas rumphii* forma *papuana* (F.Muell.) Kaneh., J. Jap. Bot. 14(9): 587 (1938).

Lectotype (fide Hill 1994b): Papua New Guinea, Western, Fly River, *D'Albertis s.n.* (lecto MEL 68056 (photo NSW); isolecto K).

Literature: Beccari (1877 as *C. rumphii*), Lauterbach (1900 as *C. circinalis* in part), Hill (1994b).

Illustrations: Schuster (1932 as *C. circinalis* subsp. *papuana*, figs 10J and 11H), Hill (1994b, fig. 5).

Etymology: from its original collection from the British Territory of Papua.

Vernacular: *Warnara* (Unident language) (Bailey 1909, Bonta & Osborne 2007).

Stems arborescent, to 2.8 m tall. *Leaves* bright green (bluish when new), semiglossy, 100–130 cm long, slightly keeled (opposing pinnae inserted at 130–160° on rachis), with 180–250 leaflets, with white and orange tomentum shedding as leaf expands; rachis usually terminated by a spine; petiole 30–40 cm long (25–35% of total leaf), glabrous, unarmed; basal leaflets not gradually reducing to spines, 30–90 mm long. *Median leaflets* simple, weakly discolorous, 80–130 mm long, 6–9 mm wide, inserted at 60–80° to rachis, decurrent for 1.5–5 mm, narrowed to 3.5–5.5 mm at base (to 55–65% of maximum width), 5.5–14 mm apart on rachis; section flat; margins flat; apex acute, not spinescent; midrib raised above, raised below. *Cataphylls* linear, pungent, pilose, densely orange-tomentose. *Pollen cones* ovoid, orange, 15–20 cm long, 810 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, c. 24 mm long, c. 10 mm wide, fertile zone c. 17 mm long, sterile apex c. 7 mm long, level, apical spine rudimentary, sharply upturned, 1–5 mm long. *Megasporophylls* 16–20 cm long, brown-tomentose; ovules 2–6, glabrous; lamina lanceolate, 35–50 mm long, 17–25 mm wide, regularly dentate with 14–20 pungent lateral spines, 2–4 mm long; apical spine distinct from lateral spines, 8–15 mm long. *Seeds* flattened to ovoid, 32–35 mm long, 25–29 mm wide; sarcotesta orange-brown, not pruinose, 1.5–2.5 mm thick; fibrous layer absent; sclerotesta smooth; spongy endotesta absent.

Historical notes: the basis of this species was cited only as 'On the Fly-River; D'Albertis. The two sheets MEL68056 and MEL68057 (photos NSW) apparently collected by D'Albertis were annotated only by Mueller, and do not bear D'Albertis' name. A portion of the former was sent to K by Mueller, according to his annotation on the sheet. The sheet MEL68056, annotated by Mueller 'parofolii supera / Fly-River', is more comprehensive, and has been designated the lectotype.

Distinguishing features: *Cycas papuana* is nearest to *C. armstrongii* Miq., differing in the longer leaves with longer petioles and more leaflets (*C. armstrongii* has leaves 55–90 cm long with petioles 10–25 long and 160–220 leaflets). The long, unarmed petiole resembles that of *C. conferta* Chirgwin & Wigston, which differs in the somewhat shorter leaves (70–110 cm long) with more closely crowded leaflets (spaced at 4.0–7.0 mm on rachis), less extended sterile apex on the microsporophylls (6–8 mm long), and larger seeds (36–40 mm long). Both *C. armstrongii* and *C. conferta* are endemic in the Northern Territory of Australia.

Distribution and habitat: Papua New Guinea, Western District, from the flood-plains of the Fly River and around Daru west at least to the Bensbach River. A sporadic but widespread component of savanna woodlands on flat country, sometimes locally abundant. Also present across the border in Indonesian territory (Wasur National Park). Fig. 1.

Conservation status: abundant and apparently not at risk. Although in a national park in Indonesia, there is significant land use pressure in this area, and conservation is somewhat in doubt in this region. Ver 3.1:IUCN (2001) status is **NT** (Donaldson 2003) for Indonesia and PNG.

Selected specimens examined: INDONESIA: Papua: Merauke, Tanah Miring, 10 November 2002, Hambali, Gregory s.n. (NSW).

PAPUA NEW GUINEA: Western: Mabaduan, *Brass 6541*, Apr 1936 ([A], BRI, LAE); Mausa, c. 15 km W of Morehead, on Morehead to Weam road, *Conn 3523 & Jacobs*, 26 Sep 1990 (NSW, LAE); Sibidiri, Morehead Subdistrict, *Foreman et al. LAE60493*, 22 Jul 1974 (LAE, BRI, CANB, A[n.v.], K, L, QRS [n.v.]); 2 km W of Ioka, Daru Subdistrict, *Foreman et al. LAE60454*, 19 July 1974 (LAE, CANB, A [n.v.], L, QRS [n.v.]); Mabaduan Hill, Daru Subdistrict, *Foreman & Stocker LAE59094*, 24 Jul 1974(LAE, BRI, CANB, A [n.v.], BRI [n.v.], L, QRS [n.v.]); 1 km N of Buji, mouth of Mai Kussa River, *Harris 138*, 9 Nov 1974 (DNA); next to Bensbach Wildlife Reserve office, *Rau UPNG6800*, 7 Dec 1982 (LAE, DNA, MEL [n.v.]).

Excluded names

Cycas rumphii var. subinclusa Schuster., Pflanzenr. 99:75 (1932).

Type: the illustration, Schuster, Pflanzenr. 99:75 Fig. 12 Y-Z (1932)

The type drawing appears to have been made from dried material of a plant cultivated at the Botanical garden in Utrecht. The epithet refers to the way the ovules are held on the megasporophyll. However this character appears to be an artifact of the drying process. This drawing lacks the megasporophyll lamina, which is crucial for correct identification. Schuster clearly states 'Laminae macrosporophyllii profunde pinnatifidae'. Judging by Schuster's confused concept of *C. rumphii* and the statement of a "very pinnatifid megasporophyll lamina", this name should not be further associated with *C. rumphii*. Without a complete megasporophyll lamina it will forever be impossible to correctly identify this taxon. No herbarium specimens are known to exist that can be related to this description or the cultivated plant. The cultivated plant can no longer be located.

Cycas corsoniana G.Don, Gard. Mag. & Reg. Rural Domest. Improv. 18: 371 (1842); name only, in syn. (Schuster 1932). *Zamia corsoniana* G. Don, Gard. Mag. & Reg. Rural Domest. Improv. 18: 371 (1842); name only.

Cycas corsoniana G.Don was one of four newly described taxa discovered by Mr. James Corson during his trip to the "South Seas". The locality was said to be Batagoda and (!) Geby. It has not been possible to trace these localities even to country of origin. The description states "scales of strobile cuneated, each with an incurved hook at top, on the upper face". The mention of the spinose tip on the microsporophyll, which is so long that it is curved is interesting as *C. rumphii* has no, or only a rudimentary spinose tip on the microsporophyll. This name should not be associated with *C. rumphii*, although it may be matched with another taxon in the *Rumphiae* subsection. The type specimen has not yet been located and does not exist in the Linnean Society Herbarium but may be in the herbarium of the late Professor Don. The Don collection was auctioned to the Natural History Museum of London (Lot no. 254) in the sale of 10th November 1863.

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New combinations in *Zostera* (Zosteraceae)

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Abstract

Systematic studies have clarified interspecific relationships in *Zostera*, but also allow for different but phylogenetically compatible classifications. Recently, several new species have been assigned to the genus *Heterozostera*, which some prefer to retain as a subgenus within *Zostera*; thus, if this taxonomic interpretation is followed, appropriate names do not exist in *Zostera*.To address this problem, we provide three new combinations (***Zostera chilensis, Z. nigricaulis*** and ***Z. polychlamys***) for species from Chile and Australia, that have been described in *Heterozostera*. We also present a brief account of the conflicting classifications available for Zosteraceae.

Introduction

By analysing both molecular and morphological data, Les et al. (2002) demonstrated that *Heterozostera* is nested phylogenetically within *Zostera*. The DNA and morphological cladograms presented by Les et al. (2002) are consistent with a number of options for maintaining monophyletic taxa within Zosteraceae, and there have been at least three ways proposed for resolving the classificatory problem:

(i) recognise one genus, *Zostera* (with two or three subgenera), treating *Heterozostera* as a synonym of the former genus;

(ii) recognise three genera, namely, *Zostera, Heterozostera* and *Nanozostera*; or

(iii) recognise two genera, namely, *Zostera* and *Nanozostera* (including *Heterozostera*).

Tomlinson and Posluszny (2001) adopted option (ii) by elevating the former *Zostera* subgenus *Zosterella* Aschers. to generic rank as *Nanozostera*, an approach that has not yet been widely followed. In our estimation, this option appears to be the least optimal because it introduces a new name for a taxon already widely recognised as a subgenus and would require the unnecessary abandonment of taxonomic names that have been in use for more than a century. Furthermore, the proposed genera would be difficult to delimit morphologically; e.g., a morphological phylogenetic analysis depicted the three taxa as an unresolved polytomy (Les et al. 2002). It also seems excessive to segregate the less than 15 total species as three separate genera with rather weak morphological distinctions.

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Consequently, Les et al. (2002) proposed that only one genus should be recognised, namely *Zostera* (option [i], above). Their recommendation was made because that option provided the highest level of nomenclatural stability and avoided a proliferation of names within this small group of morphologically similar plants.

Phylogenetic analyses by Tanaka et al. (2003) resolved the same basic clades as those found by Les et al. (2002). These authors did not advocate adoption of a specific classification, but suggested yet another option (iii), which was to merge subgenus *Zosterella* and the genus *Heterozostera* under the name of the recently described *Nanozostera*. However, that option would not be valid nomenclaturally, given that such a merger would require the use of the oldest name available at the rank of genus. In this case, that name would be *Heterozostera* (named by Hartog in 1970) rather than *Nanozostera* (named by Tomlinson & Posluszny in 2001).

Phylogenetic analyses by Kato et al. (2003) also mirrored the results of Les et al. (2002), by recovering essentially the same three clades of *Zostera* species. However, those authors advocated the adoption of the 'option (iii)' classification suggested by Tanaka et al. (2003), i.e., two genera (*Zostera*, *Nanozostera*), with *Heterozostera* merged within the latter. Consequently, these authors also failed to recognise the nomenclatural priority of the name *Heterozostera* at the genus level. Further nomenclatural confusion is evidenced by their proposed establishment of only two subgenera within *Nanozostera* (*Heterozostera*, *Zosterella*), neither representing the required autonym (i.e., subgenus *Nanozostera*) which would be established by the presence of the type species of the genus. In any case it is clearly evident that option (iii) should not be considered for classification of *Zostera* species because it is invalid nomenclaturally.

Kuo (2005) published a revision of *Heterozostera*, using morphological and anatomical characters to distinguish four taxa from what originally had been considered a single species (*Heterozostera tasmanica*). This work followed the classification option (ii), retaining *Heterozostera* as one of the four generic segregates advocated by Tomlinson and Posluszny (2001). However, no rationale for following that particular classification was provided. As a result, Kuo (2005) named three new species of *Heterozostera*, that, if they are to be treated as species of *Zostera*, currently lack combinations in that genus.

We make no evaluation of the validity of the new *Heterozostera* species proposed by Kuo (2005); however, we continue to advocate that any species related phylogenetically to the clade containing the former *Heterozostera tasmanica* should be assigned to the genus *Zostera*. A more detailed rationale for our preference is provided in Les et al. 2002), but is summarised here.

The generic distinction of *Zostera* and *Heterozostera* has been disputed, mainly because of the uncertainty of the reliability of apparent diagnostic taxonomic characters. Several taxonomists have remarked on the difficulty of separating the morphologically similar *Zostera* and *Heterozostera* (Aston 1973; Jacobs & Williams 1980). Aston (1973) and Phillips and Meñez (1988) essentially followed Hartog (1970) who distinguished the two genera based on a distinction between monopodial rhizomes as found in *Zostera* compared to sympodial (unbranched) rhizomes in *Heterozostera*. However, Tomlinson (1982) and Soros-Pottruff and Posluszny (1995) have shown that this often-cited sympodial feature is erroneous and should not be used to distinguish the genera. Robertson (1984) followed Tomlinson's (1982) recommendations and considered both *Heterozostera* and *Zostera* as having monopodial, herbaceous rhizomes. Instead, she relied on the difference in cortical vascular bundle number (employed as the secondary key character by Hartog 1970) and retinacule shape to separate the genera. However, Yip (1988) later showed that overlap exists in the number of cortical bundles in *Zostera* (2–4) and *Heterozostera* (2–12). Therefore *Heterozostera*, as circumscribed originally by Hartog (1970), cannot be supported.

Although Soros-Pottruff and Posluszny (1995) clarified the rhizome type in *Heterozostera* and *Zostera* (both monopodial), their clarification provided for a new method of distinguishing between the taxa, namely, an undulating growth pattern that, in the family, is apparently unique to *Heterozostera*. Soros-Pottruff and Posluszny (1995) also included the presence of wiry, erect stems, a tendency toward increased cortical vascular bundles, and lack of vascularisation in retinacules as additional features that separate *Heterozostera* from *Zostera*. Les et al (2002) added retinacule morphology as another useful diagnostic feature, which is described as lanceolate in *Heterozostera* and triangular to suborbicular in *Zostera* (Roberts 1984). Within Zosteraceae, Hartog (1970) described the retinacules as elongate, hence long (2.5–14 mm long) in *Phyllospadix*, moderately long (2–3 mm) in *Heterozostera* and either short (0.5–1.75 mm) or absent in *Zostera*. The longer (>2 mm) retinacules of *Heterozostera* appear to effectively separate it from *Zostera* (<1.75 mm) without overlap.

Even though some of the distinctions made between *Heterozostera* and *Zostera* in past treatments have proven to be flawed, a modified set of characters could be used effectively to separate these taxa taxonomically. In addition to these distinctions, Kuo and McComb (1998) suggest that *Heterozostera* is probably a hexaploid, a unique ploidy level in the family. Hence, the major issue with *Heterozostera* is not whether it is distinct taxonomically, but rather which taxonomic rank is most appropriate given the observed differences. Are undulating rhizomes, additional vascular bundles, and long, unvascularised retinacules sufficient to separate *Heterozostera* and *Zostera* at the generic level?

The circumscription of ranks (genera, sections, species) always involves some subjectivity, but greater objectivity can be achieved by the satisfaction of phylogenetic criteria that taxa should represent monophyletic groups (Judd et al. 1999). Morphological data alone cannot effectively answer this question because of their low resolving power. If the topology of the majority rule consensus tree (Les et al 2002) is used as a guideline, then *Heterozostera* must either be combined with *Zostera*, or four separate genera of Zosteraceae recognised to avoid paraphyletic taxa.

However, the approach taken recently by Tomlinson and Posluszny (2001), seems unnecessarily excessive. Tomlinson and Posluszny (2001) proposed the adoption of a new genus *Nanozostera* to accommodate species in *Zostera* subgenus *Zosterella*. They provided no new data, but essentially echoed the results of Soros-Pottruff and Posluszny (1995) as the basis of their generic segregation. Because neither study analysed phylogenetic relationships, the conclusions were based on perceived morphological incongruities. However, the morphological cladistic analyses of Les et al. (2002) indicate that none of the genera recognised by Tomlinson and Posluszny is particularly well-defined morphologically, especially when compared to the genus *Phyllospadix*. *Nanozostera* is defined by only two morphological synapomorphies, *Zostera* (sensu stricto) by three synapomorphies, and *Heterozostera* by four synapomorphies. In perspective, *Zostera noltii* and *Z. japonica* are differentiated from the other members of *Zostera* subgenus *Zosterella* also by only two synapomorphies, yet have never been considered as separate genera. This level of differentiation is miniscule when compared to *Phyllospadix* which is separated from these taxa by 19 morphological apomorphies. Comparatively, the low level of morphological differentiation would support the merger of *Heterozostera*, plus *Nanozostera*, into a single genus (*Zostera*) and with the family consisting of the latter genus and *Phyllospadix*.

The pattern of nucleotide divergence is similar proportionately; e.g., with *Phyllospadix* differing substantially from all other Zosteraceae (21.8–26.7%) and none of the remaining taxa exhibiting more than 16.8% (mostly <8.0%) nucleotide divergence (Les et al. 2002). Although relative nucleotide divergence can provide interesting evolutionary insights, we believe that major taxonomic distinctions (such as delimitation of genera) should rely principally on morphological characters if any practical utility is to be achieved.

In summary, the phylogenetic analyses of Zosteraceae by Les et al. (2002) resolved the same four clades using molecular or morphological data, either singly or in combination. Although each clade could be recognised as a distinct genus in a cladistic sense, doing so would, in our opinion, create several highly similar and weakly differentiated genera. However, phylogenetic analyses of Zosteraceae by several groups of researchers consistently demonstrate no support for the circumscription of *Heterozostera* as proposed originally by Hartog (1970). If that genus is to be retained, it must also be redefined to include *Zostera* subgenus *Zosterella* if phylogenetic integrity is to be maintained. In such an instance, the generic name *Heterozostera* would have nomenclatural priority.

Our suggestion is to recognise only two genera in Zosteraceae, namely *Zostera* and *Phyllospadix*, which we believe to most usefully depict the major phylogenetic lineages within this family as these two genera are well differentiated at both the morphological and molecular levels. The three subclades within *Zostera* should continue to be recognised as subgenera, namely as *Zostera* subg. *Zostera*, subg. *Heterozostera* and subg. *Zosterella*.

Here we provide the new combinations that are necessary for the implementation of this option (i.e. option i).

New combinations (*Zostera* subgenus *Heterozostera*)

Zostera chilensis (J.Kuo) S.W.L.Jacobs & D.H.Les **comb. nov.**

Basionym: *Heterozostera chilensis* J. Kuo (2005; 126–127).

Type: Chile: Aldea, Puerta, Coquimbo Province, drift, January. 1997, *H. Kirkman and M. Edding* (holo.: US; iso: K, MEL).

This is the name that should be used for all Chilean specimens previously treated as *Heterozostera* (mostly as *H. tasmanica*).

Zostera nigricaulis (J.Kuo) S.W.L.Jacobs & D.H.Les **comb. nov.**

Basionym: *Heterozostera nigricaulis* J. Kuo (2005; 110–124).

Type: Australia: South Australia: Kangaroo Island, site 91, 21 November 1977, *H. Kirkman* (CSIRO 1988) (holo: AD; iso: PERTH).

This is the most widespread and common of the new species and most Australian references to *H. tasmanica* from the eastern States refer to this species.

Zostera polychlamys (J.Kuo) S.W.L.Jacobs & D.H.Les **comb. nov.**

Basionym: *Heterozostera polychlamys* J.Kuo (2005; 124–126)

Type: Australia: Western Australia: Flinders Bay, drift, 11 December 1990, *H. Kirkman* (CSIRO 1751; CMM 260, 261) (holo: CANB; iso L, MEL, PERTH).

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Chromosome numbers in some Mosses from New Zealand

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Abstract

Additional chromosome information, based on meiotic studies, is reported here for 27 species (of which eight are endemic) in 22 genera of New Zealand mosses in the following 14 families: Amblystegiaceae, Bartramiaceae, Bruchiaceae, Dicnemonaceae, Ditrichaceae, Funariaceae, Hypnaceae, Hypopterygiaceae, Lembophyllaceae, Leptostomaceae, Pottiaceae, Ptychomniaceae, Racopilaceae, Rhizogoniaceae. When added to the previous chromosome number records for 39 species, data are now available for 66 species.

Introduction

The New Zealand moss flora has proved of great interest for a long time (Dixon 1913–1929, Sainsbury 1945, 1955, Allison 1971, Allison & Child 1971, Bartlett 1984, Beever et al. 1992) and its bryoflora has been well studied taxonomically with the report of at least 525 mosses, 500 hepatics and 15 hornworts (Fife 1985, 1996). However, chromosome studies of New Zealand bryophytes are relatively few as noted by Fife (1996). There have been some further chromosome records published since 1994 e.g. for Bryaceae, *Dicranoloma* (Dicranaceae), *Hypnodendron* in which the low numbers n=4, 5 were recorded, Orthotrichaceae, Polytrichaceae, Sematophyllaceae families for which no additional reports are given here. These are listed in Table 1, together with the references, bringing reports available, prior to these studies, to 39 species in 22 genera of mosses.

Materials and Methods

The techniques used follow those in Ramsay (1974, 1983) with mainly meiotic studies using aceto-orcein or aceto-carmine squashes. Slides were made permanent by freezing with carbon dioxide and mounting in euparal so that many of the slides still remain suitable for study, after more than 30 years. Vouchers for chromosome counts will be deposited at the National Herbarium of New South Wales (NSW).

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Table 1. Previously published chromosome number records for New Zealand mosses

Family and Species	Chromosome number	Reference
Amblystegiaceae		
Sanionia uncinata	2n=20	Przywara et al. 1992
Bartramiaceae		
Breutelia pendula	n=6	Przywara et al. 1992
Philonotis tenuis	n=6	Newton 1973
Bryaceae		
Ochiobryum blandum (as *Bryum blandum*)	n=11	Ramsay & Spence 1996
Gemmabryum sauteri (as *Bryum sauteri*)	n=10	Ramsay & Spence 1996
Dicranaceae		
Dicranoloma billarderi	n=12	Przywara et al. 1992
Dicranoloma billarderi	n=12	Ramsay 2006
Dicranoloma dicarpum	n=7	Ramsay 2006
Dicranoloma plurisetum	n=8	Ramsay 2006
Dicranoloma platycaulon	n=7	Ramsay 2006
Dicranoloma robustum [includes *Dicranoloma cylindropyxis*]	n=7	Ramsay 2006
Dicranoloma menziesii	n=8	Ramsay 2006
Hypnaceae		
Ctenidium pubescens	n= 8	Nishimura & Inoue 1985
Hypnodendraceae		
Hypnodendron arcuatum	n=9	Ramsay 1987
Hypnodendron colensoi	n=5	Ramsay 1987
Hypnodendron comatum	n=4	Ramsay 1987
Hypnodendron comosum	n=4	Ramsay 1987
Hypnodendron kerrii	n=9	Ramsay 1987
Hypnodendron marginatum	n=9	Ramsay 1987
Hypnodendron menziesii	n=5	Newton 1973
Hypnodendron spininervium	n=9	Ramsay 1987
Hypopterygiaceae		
Cyathophorum bulbosum	n=5	Newton 1973
Hypopterygium didictyon (as *H. novae-seelandiae*)	n=6	Newton 1973
Lembophyllaceae		
Acrocladium chlamydophyllum	2n=22	Przywara et al. 1992
Orthotrichaceae		
Orthotrichum calvum	n=6	Ramsay & Lewinsky 1984
Orthotrichum tasmanicum var. *tasmanicum*	n=6	Ramsay & Lewinsky 1984, Ramsay 1993
Orthotrichum graphiomitrium	n=6	Ramsay & Lewinsky 1984
Orthotrichum hortense	n=6	Ramsay & Lewinsky 1984
Ulota lutea	n=11	Ramsay 1993
Ulota viridis	n=11	Ramsay 1993
Zygodon intermedius	n=11	Ramsay 1993
Zygodon minutus	n=16	Ramsay 1993
Macrocoma tenue	n=11	Ramsay & Vitt 1986
Macromitrium gracile	n=9	Ramsay & Vitt 1986
Macromitrium grossirete	n=9	Ramsay & Vitt 1986
Macromitrium submucronifolium	n=10	Ramsay & Vitt 1986

Family and Species	Chromosome number	Reference
Macromitrium longipes	n=9	Ramsay & Vitt 1986
Macromitrium microstomum	n=11	Ramsay & Vitt 1986
Macromitrium gracile	n=9	Ramsay & Vitt 1986
Ptychomniaceae		
Ptychomnium aciculare	n=7	Przywara et al. 1992
Polytrichaceae		
Atrichum androgynum	n=14	Ramsay 1997
Notoligotrichum australe	n=7	Ramsay 1997
Polytrichadelphus magellanicus	n=7	Ramsay 1997
Sematophyllaceae		
Warburgiella leucocyta	n=11	Ramsay et al. 2002

New Chromosome Records

Chromosome numbers already published worldwide have been obtained from indices produced by Fritsch (1991), Kuta et al. (1990) and Goldblatt and Johnson (1994–2006). New counts for 27 species in 22 genera and 14 families, with the collector and collector's specimen number and locality details are listed in Table 2.

Taxa endemic to New Zealand (8 species) are indicated thus *.

Family Amblystegiaceae

The subfamily Campylioideae was raised to the status of family as Campyliaceae by W.R. Buck (Buck & Goffinet 2000) with 18 genera including *Drepanocladus, Warnstorfia* and *Sanionia* which occur in New Zealand. However, more recent studies of the family based on nuclear and chloroplast DNA by Hedenas et al. (2002) and Goffinet and Buck (2004) have returned this family to the Amblystegiaceae

The genus *Drepanocladus* (Müll.Hal.) G.Roth was divided into several genera, e.g. *Sanionia, Warnstorfia* (Goffinet & Buck 2004, Fife 1995) with two species – *Drepanocladus aduncus*, and *D. polygamus* (*Campylium polygamus*) now recognised for New Zealand. The chromosome numbers n=10, 11, 12, 20, 22, 24 have been recorded for *D. aduncus* (Fritsch 1991, Goldblatt & Johnson 1996) from Europe, USSR, USA. Former chromosome number reports for *Sanionia uncinata* (as *Drepanocladus*) include n=10, 11, 12, 20, 30 from Europe, North America and Japan (Fritsch 1991, Goldblatt & Johnson 1996).

Chromosome numbers are determined here for one species of *Drepanocladus*, and one of *Sanionia* in New Zealand. These are the first for *Drepanocladus* while Przywara et al. (1992) recorded 2n=20 for *Sanionia uncinata* from sporophytic mitosis (Table 1) for New Zealand

1. ***Drepanocladus aduncus*** (Hedw.) Warnst. n=10, **Fig. 1.1**

The New Zealand population (Table 2) had the number n=10 which corresponds to one of the numbers reported overseas.

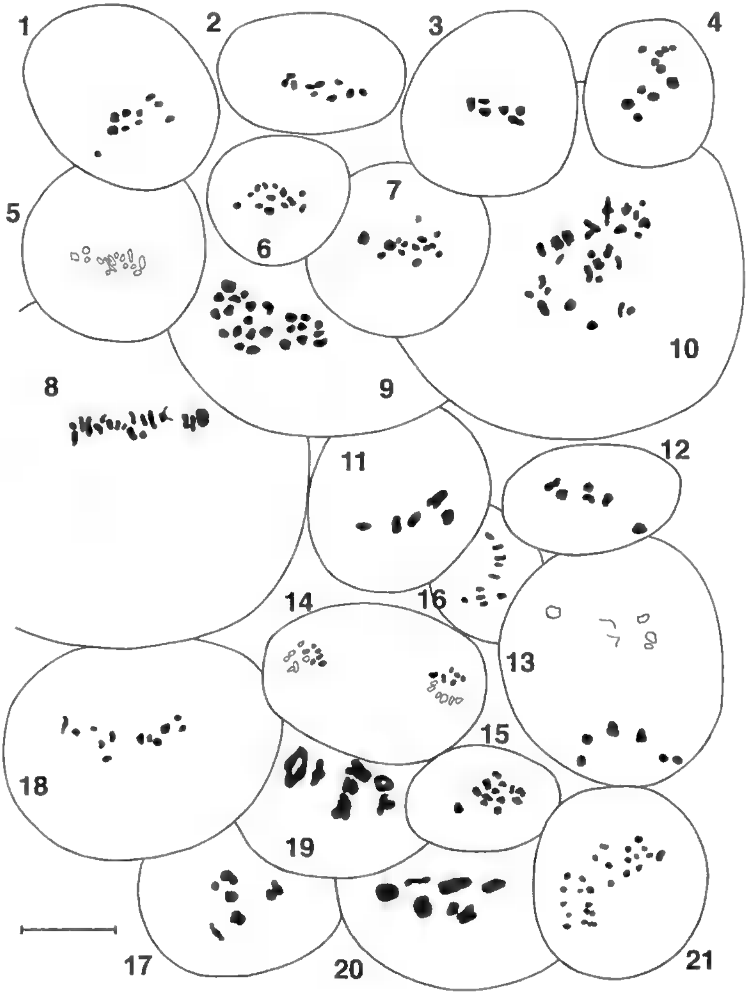

Fig. 1. Meiotic chromosomes in New Zealand mosses. **1.** *Drepanocladus aduncus* (84/84) n=10; **2.** *Sanionia uncinata* (75/84) n=10; **3.** *Philonotis pyriformis* (41/87) n=6; **4.** *Rhynchostegium tenuifolium* (63/84) n=11; **5.** *Trematodon suberectus* (43/87) n=14; **6.** *Ditrichum brachycarpum* (7/84) n=13;. **7.** *Ditrichum brevirostre* (20/87) n=13; **8.** *Entosthodon* species 1 (79/84) n=18; **9.** *Entosthodon laxus* (1/84 n=24; **10.** *Entosthodon* species 2. (97/84) n=26. **11.***Cyathophorum bulbosum* (13/83) n=5; **12.** *Hypopterygium didictyon* (7/80) n=6; **13 & 14** *Leptostomum inclinans* (84/84) n=6. **13.** Anaphase I showing the six half bivalents moving to opposite poles; **14.** Anaphase II showing two Metaphase II plates with 6 chromosomes separating to each end. **15.** *Tortella mooreae* (1/86) n=13; **16.** *Racopilum cuspidigerum var. convolutaceum.* (29/87) n=10; **17.** *Cryptopodon bartramioides* (56/84) n=7; **18.** *Tortula breviseta* (85/84) n=12; **19.** *Dichelodontium nitidum* (101/84) n=7, note smallest bivalent separated early; **20.** *Cladomnion ericoides.* (104/82) n=7; **21.** *Weissia austrocrispa* (58/83) n=26; scale bar 10 µm

Table 2. Additional chromosome records for New Zealand mosses (alphabetical by genus). Unless otherwise stated, collections were made by the author; often with J.E. Beever as my guide on either the North Island (NI) and/or South Island (SI) of New Zealand. JEB – Jessica Beever; AJF Allan J. Fife. Taxa endemic to New Zealand (8 species) are indicated thus *. Vouchers will be deposited at the National Herbarium of New South Wales (NSW).

Taxon	Chromosome number (n)	Voucher specimen & locality data
Acrocladium chlamydophyllum	11	72/84 NI, Mt Ruapehu.
**Cladomnion ericoides*	7	104/84 NI, Mt Ruapehu
**Cryptopodium bartramioides*	7	67/84 NI, Renata track; Akatarawas; 56/84, Kapakapanui track, Akatarawas
Ctenidium pubescens	8	NI, JEB 21-14, Rangitoto Is.; JEB 27-15 Little Barrier Is
Cyathophorum bulbosum	5	13/83 SI, Leith Saddle, Dunedin HPR with J. Child
**Dichelodontium nitidum*	10	62/84 NI, Mt Ruapehu, 101/84 NI, Mt Ruapehu
Dicnemon calycinum	7	102/84 NI, Mt Ruapehu
**Dicnemon semicryptum*	7	107/84 NI, Mt Ruapehu,
**Ditrichum brachycarpum*	13	7/84 SI, Milford Sound L.E. Anderson 65/84 NI, Mt Ruapehu.
Ditrichum brevirostre	13	20/87 SI, Red Hills,
Drepanocladus aduncus	10	84/84, NI, Mt Ruapehu
Entosthodon laxus	24	1/84 SI, AJF
Entosthodon sp. 1	18	79/84 SI, AJF
Entosthodon sp. 2	26	97/84 NI, Mt Ruapehu
Glyphothecium sciuroides	7	61/84 NI Mt Ruapehu
Hypopterygium didictyon	6	7/80 SI, with J. Child
Leptostomum inclinans	6	82/84 NI, Mt Ruapehu
**Philonotis pyriformis*	6	41/87 SI, Lake Rotoroa
Ptychomnion aciculare	7	7/83 NI, Waitakere Ra.
Racopilum cuspidigerum var. convolutaceum	10	29/87, SI, Red Hills
Rhynchostegium tenuifolium	11	77/84 NI, Mt Ruapehu 63/84 NI, Mt Ruapehu
Sanionia uncinata	10	75/84 NI, Mt Ruapehu
**Tortella mooreae*	13	1/86, 2/86 NI, Rangitoto Is., JEB 38-27, 38-28
Tortula breviseta	12	83/84, 85/84 NI, Mt Ruapehu
**Trematodon suberectus*	14	8/83, NI, JEB 21-32, Ngaruawahia, S. Auckland 43/87 SI, Lake Rotoroa
Weissia austrocrispa	26	58/83 SI AJF

2. *Sanionia uncinata* (Hedw.) Loeske n=10, **Fig. 1.2**

The New Zealand population studied here was epiphytic on tree bark in the Wakapapanui alpine garden on Mt Ruapehu (Table 2) and had the meiotic chromosome number n=10. This gametophytic count corresponds to the previous sporophytic count of 2n=20 by Przywara et al. (1992).

Family Bartramiaceae

Beever et al. (1992) report three species of *Philonotis* from New Zealand. The mitotic chromosome number of n=6 was recorded for *Philonotis tenuis* from the South Island by Newton (1973). Previous chromosome records for other species in the genus are n=6, 12 (Fritsch 1991, Goldblatt & Johnson 2000) from Europe, India, Japan, Australia, China and Chile.

***3. *Philonotis pyriformis* (R.Br. bis) Wijk & Margad. n=6, Fig. 1.3**

The chromosome number of n=6 is reported here for *Philonotis pyriformis* and represents the first record for this species in New Zealand. (Table 2). The number and morphology of the six bivalents at meiosis correspond to those reported for other *Philonotis* species.

Family Brachytheciaceae

The family Brachytheciaceae in New Zealand includes the genera *Brachythecium, Rhynchostegium, Eurhynchium* with several species in each as well as several smaller monospecific genera (Beever et al. 1992). There are no previous chromosome records from New Zealand for this family. The chromosome numbers n=8, 10, 11, 12, 14, 20, 22 have been recorded from India, Europe, Japan and Australia for a number of species of *Rhynchostegium* with some of these including an m-chromosome (Fritsch 1991). Previous studies record the chromosome numbers n=20+2m, 22 and polyploid numbers for specimens of *R. tenuifolium* (including those under *R. laxatum*) from Australia (Ramsay 1974).

4. *Rhynchostegium tenuifolium* (Hedw.) Reichardt n=11, Fig. 1.4

In New Zealand (Table 2) the number n=11 was recorded for both populations studied. These had a haploid complement and were not polyploid as were those recorded for Australia so far (Table 1).

Family Bruchiaceae

The genus *Trematodon,* formerly in the Dicranaceae, has been placed in the Bruchiaceae in the recent classification by Goffinet and Buck (2004). Previous chromosome records for *Trematodon* from the Northern Hemisphere (India, U.S.A., Canada, Alaska see Fritsch 1991, Ireland 1991 in Goldblatt & Johnson 1994) are n=11, 13+m, 13+2m, 14, 14+m with polyploids n=28, 28+m, 28+2m, some cytotypes including one or two 'm' chromosomes.

***5. *Trematodon suberectus* Mitt. n=14, Fig 1.5**

T. suberectus is one of three species of *Trematodon* recorded for New Zealand (Beever et al. 1992). The chromosome number n=14 is reported here for *T. suberectus* in two separate collections (Table 2) and is the first record for this genus from New Zealand.

Family Dicranaceae [Dicnemonaceae]

The southern hemisphere family Dicnemonaceae, formerly a subfamily of the Dicranaceae was validated as a family by Brotherus (1924) who recognised five genera. In a later analysis of the family, Allen (1987) retained only *Dicnemon, Eucamptodon* and *Synodontium* while Buck and Goffinet (2000) transferred *Synodontium* elsewhere retaining only *Dicnemon and Eucamptodon.* The genus *Dicnemon* is reported from New Guinea, Vanuatu, New Caledonia, Australia and New Zealand while *Eucamptodon* is distributed in Australia, New Caledonia and South America but is absent from New Zealand (Allen 1987). More recent studies based on DNA analyses (Hedenas et al. 2002, Goffinet & Buck 2004) have returned the Dicnemonaceae to the Dicranaceae.

Observations of sporocytes under light microscopy indicate that the nucleus and cytoplasm are at one end of the sporocyte, while a large vacuolar area exists at the other end. Sporocytes are smaller and rectangular in *D. calycinum* (Fig. 2.1) and larger more oval in *D. semicryptum* (Fig. 2.2). In *Eucamptodon* the sporocytes are spherical with a central nucleus as in other mosses.

The sporocytes in *Dicnemon* are arranged as a single layer around the columella and following meiosis form a ring of 8–12 spores in cross section and 8 columns in rows longitudinally (Allen 1987). At the time of meiosis in these studies the capsule was green and translucent with a coloured annulus in *Dicnemon semicryptum* but in *D. calycinum* the annulus coloured later, after spores were produced. The operculum and peristome became coloured at the young spore stage in both species.

Following meiosis and early spore formation, rapid and simultaneous mitoses lead to the production of large multicellular spores (to 700 µm). In both *D. semicryptum* and *D. calycinum* they are freed from the capsule as tetrahedral protonema.

These are not shed directly but the columella dries out and the multicellular protonemata are dislodged by splashing in heavy rain, i.e. in conditions suitable for germination.

There are no previous chromosome records for *Dicnemon* and none yet for *Eucamptodon*.

6. *Dicnemon calycinum* (Hook.) Schwägr. n=7, Fig. 2.1

The chromosome number n=7 was obtained for *Dicnemon calycinum* (Table 2) at anaphase I with seven half bivalents moving to each pole. Meiosis occurs towards one

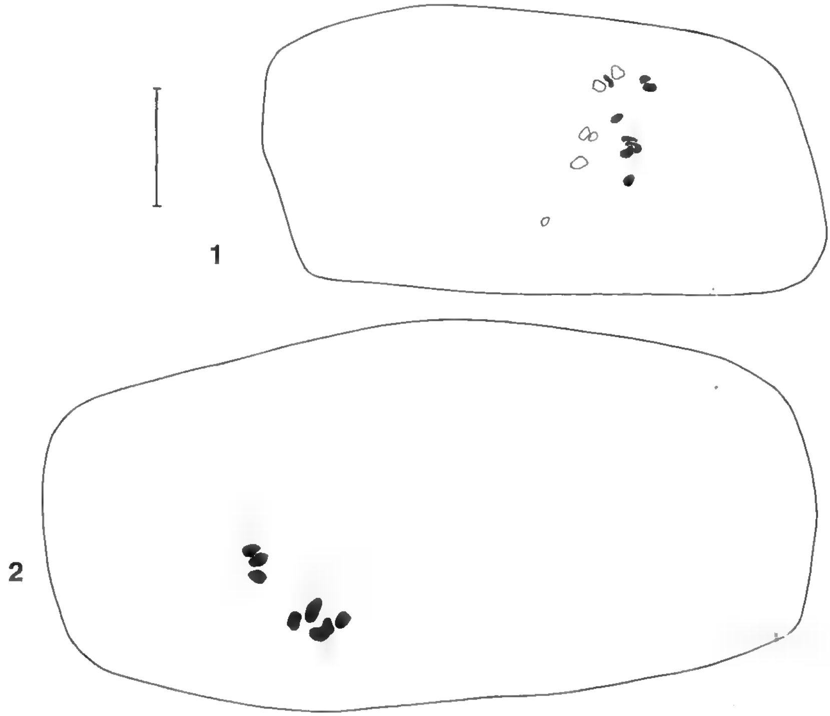

Fig. 2. Chromosome numbers in *Dicnemon* – large sporocytes with meiotic chromosomes towards one end of cell; **1.** *Dicnemon calycinum (107/84).* Anaphase I of meiosis showing 7 half bivalents moving to each pole in the smaller sporocyte; **2.** *Dicnemon semicryptum* (102/84). Metaphase I of meiosis in larger sporocyte. Scale bar 10 µm

end of the sporocyte, not centrally as in most mosses. The sporocytes are smaller in *D. calycinum* than in *D. semicryptum*.

***7. *Dicnemon semicryptum* Müll.Hal. n=7, Fig. 2.2**

As the nucleus is situated at one end of the very large sporocyte in the specimens of *D. semicryptum* (Table 2), meiosis is also not centrally positioned. At metaphase I of meiosis the seven bivalents were fully contracted with one larger bivalent.

Family Ditrichaceae

The family Ditrichaceae contains some 24 genera (Goffinet & Buck 2004) of which eight genera including *Ditrichum, Ceratodon, Distichium, Eccremidium* and *Pleuridium*, occur in New Zealand. Of these, *Ditrichum* with 12 species (Beever et al. 1992) is the largest. Chromosome data for a number of species of *Ditrichum* from Europe, U.S.A. and India, give the number as predominantly n=13, sometimes with an additional m-chromosome or sometimes polyploids with n=26 (Fritsch 1991, Goldblatt & Johnson 1994, 1996, 2003). Chromosome numbers have been recorded for the single species *D. difficile* from Australia n=13, 13+m (Ramsay 1974) but there are no previous records from New Zealand.

***8. *Ditrichum brachycarpum* Hampe n=13, Fig. 1.6**

9. *Ditrichum brevirostre* (R.Br.bis.) Broth. n=13, Fig. 1.7

Both species of *Ditrichum* studied (Table 2), had the chromosome number n=13. The two collections of *Ditrichum brachycarpum* examined were collected at different times and in different localities on the South Island (Table 2).

Family Funariaceae

Fife (1982, 1985, 1985a, 1986, 1996) and Fife and Seppelt (2001) have revised the various taxa in the Funariaceae for Australasia. They recognise six species of *Entosthodon* (smooth capsules) and two species of *Funaria* (grooved capsules) for New Zealand.

Chromosome data are available for a number of taxa as *Entosthodon* or *Funaria* from North America, Europe, India and Australia (see Fritsch 1991, Goldblatt & Johnson 1994). A recent count (Goldblatt & Johnson 2000) for *Entosthodon wichurae* from India is n=7 representing the probable basic number of the family. Numbers for other species include n=14, 21, 24, 26, 27, 28, 42, 52, 54, 56. Information is provided here for 3 species.

10. *Entosthodon laxus (*Hook.f. & Wilson) Mitt n=24, Fig 1.9

Formerly *Funaria apophysata*, now known as *Entosthodon laxus*, has the chromosome number n=24, the first for this species for a collection from the South Island by A.J. Fife (Table 2).

11. *Entosthodon* species 1, n=18, Fig. 1.8

The chromosome number of n=18 determined here for a New Zealand collection of *Entosthodon* for an as yet unidentified species from the South Island made by A.J. Fife (Table 2) is the first with the chromosome number n=18.

12. *Entosthodon* species 2, n=26, **Fig. 1.10**

This as yet unidentified species has the chromosome number n=26 for a collection from Mt Ruapehu (Table 2).

Family Hypnaceae

The Hypnaceae is a large family of mosses with some 62 genera (Buck & Goffinet 2000). The family is not well represented in Australasia and in New Zealand only the four genera *Hypnum* (two species), *Ctenidium*, *Fallaciella* (formerly *Camptochaete gracilis*) and *Ectropothecium*, each with a single species, are present.

Chromosome numbers for the family of n=11 (five species) and n=8 (four species) have been reported for nine species from Europe, North America, New Zealand and Japan mainly by Nishimura et al. (see Fritsch 1991) based on mitotic studies. These included n=8 for *Ctenidium pubescens* in New Zealand (Nishimura & Inoue 1985).

13. *Ctenidium pubescens* (Hook.f. & Wilson) Broth. n=8.

Ctenidium is a small genus with 21 species worldwide (Nishimura 1985). In these studies of meiosis, the chromosome number for *C. pubescens* in New Zealand is confirmed as n=8. but no illustrations are included here. The collections were obtained from localities near Auckland (Table 2) close to that from which J.E. Beever obtained the specimens sent to Nishimura.

Family Hypopterygiaceae

A recent revision of the family Hypopterygiaceae by Kruijer (2002) has renamed a number of former *Hypopterygium* species. Newton (1973) reported n=6 for *Hypopterygium didictyon* (formerly *H. novae-seelandiae*) while Ramsay (1967) reported studies on a population from Australia of *H. tamarisci* (as *H. rotulatum*) with various cytotypes and the numbers n=9, 18, 27, 36. The chromosome number for *Cyathophorum bulbosum* from New Zealand examined mitotically by Newton (1973) is n=5 and is the same for Australia examined meiotically (Ramsay 1974).

14. *Cyathophorum bulbosum* (Hedw.) Müll.Hal. n=5, **Fig. 1.11**

The meiotic chromosome number recorded here for *Cyathophorum bulbosum* from Dunedin (Table 2) had the same chromosome number n=5 and similar bivalents to the Australian collections examined previously.

15. *Hypopterygium didictyon* Müll.Hal. n=6, **Fig. 1.12**

These studies provided the meiotic chromosome number of n=6 for *H. didictyon* (Table 2) confirming that determined by Newton (1973) (as *H. novaeseelandiae*) based on gametophytic mitosis.

Family Lembophyllaceae

The family Lembophyllaceae was revised by Tangney (1997) and includes eight genera of which five have representatives in New Zealand. Przywara et al. (1992) recorded the chromosome number 2n=22 based on sporophytic mitotic studies for *Acrocladium chlamydophyllum* from New Zealand. This corresponds to a meiotic count of n=11. Australian studies have previously reported the chromosome number for *Acrocladium chlamydophyllum* (Hook.f. & Wilson) Müll.Hal. & Broth. as n=11 (10+m), [as *A.*

auriculatum (Mont.) Mitt.] at meiosis (Ramsay 1974). Chromosome numbers for *Lembophyllum divulsum* (Hook.f. & Wilson) Lindb. n=10, and *Camptochaete deflexa* (Wilson) A.Jaeger [as *C. ramulosa* (Mitt.) A.Jaeger] n=10, 11, 22 and n=11 for *C. excavata* (Taylor) A.Jaeger [as *C. vaga* (Hornsch. ex Müll.Hal.) Broth.] have been recorded for Australian species (Fritsch 1991).

16. *Acrocladium chlamydophyllum* (Hook.f. & Wilson) Müll.Hal. & Broth., n=11.

The meiotic chromosome number was verified as n=11 for a population from New Zealand (Table 2) and corresponds to the sporophytic mitotic count of n=22 made by Przywara et al. (1992). No illustration is included here.

Family Leptostomaceae

The Leptostomaceae is a southern hemisphere family distributed in Australia, New Zealand and Papua New Guinea. It contains a single genus *Leptostomum* with two species in New Zealand (Beever et al. 1992). The chromosome numbers n=6, 12 have been reported previously for *L. inclinans* in Australia (Ramsay 1967, 1974).

17. *Leptostomum inclinans* R.Br. n=6, Figs. 1.13 & 1.14

This is the first chromosome count for *Leptostomum inclinans* in New Zealand (Table 2). The number n=6, (Fig. 1.13) at anaphase I corresponds to that found for Australian specimens. Many sporocytes were at metaphase II where the count could be confirmed, Fig. 1.14.

Family Pottiaceae

The family Pottiaceae contains a very large number of taxa with a high range of chromosome numbers within individual species for a number of genera such as *Tortula* (some species now recorded as *Syntrichia* by Zander (1993)), *Tortella, Trichostomum* and *Weissia.*

***18. *Tortella mooreae* Sainsbury n=13, Fig. 1.15**

Tortella mooreae is a New Zealand endemic species and the specimens examined here, collected by J.E. Beever, came from islands near Auckland, North Island (Table 2). The chromosome number, the first report for the species, was determined as n=13 in both collections.

The genus *Tortula* is a large genus of colonising mosses with many species and a wide range of chromosome numbers. There are numbers available for more than 50 species worldwide; n=7 (6+m), 12, 13, 24, 26, 28, 36, 48, 50, 52, 66 which include high intraspecific and interspecific polyploids (Fritsch 1991).

19. *Tortula brevisetacea* (F.Muell.) Thér. n=12, Fig. 1.18

There are no previous chromosome records for this New Zealand species. The number reported here (Table 2) is n=12.

Weissia is another widespread colonising genus in the Potticaceae with many species. Chromosome numbers for some species reported in Fritsch (1991) from North America, Europe, India, Japan and Australia are n=13, 14, 26.

20. *Weissia austrocrispa* (Beckett) I.G.Stone n=26, Fig. 1.21

This species (in Beever et. al. 1992 as *Astomum austrocrispum* (Beckett) Broth.) is present in New Zealand and Australia (Streimann & Klazenga 2002). The chromosome number of n=26 was obtained from specimens collected by Allan Fife (Table 2) and is the first for the species.

Family Ptychomniaceae

The family Ptychomniaceae is a southern hemisphere pleurocarpous family. There are 6 recognised genera (Buck & Goffinet 2004) including *Dichelodontium, Ptychomnion, Cladomnion, Hampeella* and *Glyphothecium. Cladomnion* is monotypic and endemic to New Zealand. The genus *Ptychomnion* has one species, *P. aciculare*, in New Zealand and Australia and another species, *P. densifolium*, found in New Zealand at high altitudes and on subantarctic islands. The chromosome number n=7 has been recorded previously for Australian species of *Glyphothecium* and *Ptychomnion* (Ramsay 1967, 1974).

***21. *Dichelodontium nitidum* (Hook.f. & Wilson) Broth. n=7, Fig. 1.19**

Both collections of *D. nitidum* examined here (Table 2) had the chromosome number of n=7, with comparatively large chromosomes. These are the first records for this genus and species. The number supports its relationship to other taxa in the family.

***22. *Cladomnion ericoides* (Hook.) Hook. f. & Wilson n=7, Fig. 1.20**

There are no previous chromosome number records for the genus *Cladomnion*. The number n=7 (Table 2), is reported here and includes a small bivalent (not an m-bivalent) which disjoins early. This is the same number as for the related genus *Ptychomnion* both here and in Australia and the other genera in the family studied here.

23. *Ptychomnion aciculare* (Brid.) Mitt., n=7.

The chromosome number n=7 was reported for *P. aciculare* in Australia (Ramsay 1974). This number is confirmed here for a New Zealand population (Table 2) with bivalents similar to those for Australian collections. The bivalents included one smaller one that disjoined early but was not an m-chromosome. No illustration is included here.

24. *Glyphothecium sciuroides* (Hook.) Hampe n=7.

In this study the chromosome number n=7 was reliably confirmed for two New Zealand populations (Table 2). This corresponds with the number n=7 determined previously for an Australian population (Ramsay 1974). No illustration is included here.

Family Rhizogoniaceae

The family Rhizogoniaceae is represented in New Zealand by the genera *Pyrrhobryum, Rhizogonium, Cryptopodium, Goniobryum* and *Hymenodon.* There have been a number of chromosome studies for various genera in the family, including counts of n=6, for two different species of *Pyrrhobryum* (one as *Rhizogonium paramattense*), n=12 for *Pyrrhobryum mnioides* and n=5 for *Rhizogonium novaehollandiae* in Australia (Ramsay 1974) [for photographs see figs 22–31 in Ramsay 1983] as well as n=6 and or n=12 for *P. spiniforme* (as *Rhizogonium*) from America, Japan (Fritsch 1991) and Papua New Guinea (Ramsay 2008).

Cryptopodium is a monotypic New Zealand endemic moss (Fife 1995) commonly found on the lower trunks of tree ferns.

***25. *Cryptopodium bartramioides* (Hook.) Brid. n=7, Fig. 1.17**

This is the first chromosome report for *Cryptopodium bartramioides*, determined from collections from two different localities (Table 2). The chromosomes are large and the meiotic chromosome number n=7 corresponds well with those recorded for other taxa in the family.

Family Racopilaceae

The family Racopilaceae contains two genera, *Powellia* with two species occurring in tropical regions and *Racopilum* a primarily southern hemisphere genus of 20 species occurring in South America, Africa, south-eastern Asia Australia and New Zealand. Chromosome counts of n=10 have been published for six species of *Racopilum* (Fritsch 1991) with the polyploid number n=20 for *R. tomentosum* from South America. In Australia the number n=10 was published for *R. cuspidigerum* var. *convolutaceum* as *R. convolutaceum* and also includes a collection incorrectly named as *R. strumiferum* (Ramsay 1974). *R. strumiferum*, present in New Zealand and Australia, has the number n=10 (de Vries et al. 1989, Zanten 2006) in New Zealand.

26. *Racopilum cuspidigerum* (Schwägr.) Ångstr. var. *convolutaceum* (Müll.Hal.) Zanten & Dijkstra. n=10, Fig. 1.16

This report (Table 2) confirms the number as n=10 for this taxon and is the first record from New Zealand.

Discussion

These additional studies bring the total chromosome data to 12% of the species present in New Zealand. Many taxa, including endemic species, have not been investigated There is therefore an obvious need for more cytological studies on New Zealand mosses. Such studies may highlight extra characters for the species and, where aneuploidy or polyploidy occurs, give some information on the evolution occurring both intra- and inter- specifically that may not be available from molecular studies.

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A new species of *Solanum* (Solanaceae) from the mid north coast of New South Wales

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Abstract

Solanum sulphureum A.R.Bean sp. nov. is described and illustrated. It is related to *S. brownii* and other species in the informal *S. macoorai* group, and is apparently confined to lowland rainforest in the Taree district on the mid north coast of New South Wales. Its conservation status and relationships are discussed.

Introduction

While examining a loan of *Solanum* specimens from the National Herbarium of New South Wales, I was puzzled by an unidentified specimen collected in 1983 from Killibakh Creek near Taree. At first I took it to be an introduced species, but later concluded that it was native, in view of the many character states shared with the indigenous *Solanum brownii* and its allies. Subsequent field studies have confirmed its native status.

The new species belongs in the *Solanum brownii* group, which is in turn a part of the informal *S. macoorai* group, i.e. Group 27B of Bean (2004). The *S. brownii* group now excludes *S. cinereum. S. cinereum* has previously been considered closely related to *S. brownii* (Symon 1981, Bean 2001) and was placed in the *S. macoorai* group by Bean (2004), but I now recognise that *S. cinereum* fits much more readily into the informal *S. hystrix* group (Group 25 of Bean 2004).

Nomenclature in relation to the indumentum follows Bean (2004).

Taxonomy

Solanum sulphureum A.R.Bean, **sp. nov.**

Solano brownii affinis sed foliis ovatis basi obtusis vel cordatis, pilis stellatis majoribus in partibus vegetativis, antheris brevioribus, ovario pilis stellatis carente et seminibus parvis differens.

Type: New South Wales: North Coast: 4.3 km along Somerset road, WSW of Wingham, *A.R. Bean 23356*, 29 December 2004 (holo BRI; iso NSW, MEL).

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Erect, rhizomatous perennial shrub 0.9–2.5 m high. *Adult branchlets* yellow, rusty or brown; prickles 2–15 per decimetre, straight, acicular, 5–11 mm long, 8–14 times longer than wide, glabrous; stellate hairs dense or very dense, 0.6–1 mm diameter, stalks 0.2–1.2 mm long; lateral rays 7 or 8, porrect or ascending, central ray 0.7–1 times as long as laterals, not gland-tipped; type 2 hairs dense. *Juvenile leaves* 9–12 cm long, 6–8.5 cm wide, with 2 or 3 pairs of lateral lobes, apex acute, base obtuse to cordate; prickles present on midvein and lateral veins. *Adult leaves* ovate, entire, lamina 6.5–12.3 cm long, 2.3–5.8 cm wide, 2.1–2.8 times longer than broad, apex acute, base obtuse or cordate, oblique part 0–4 mm long, obliqueness index 0–5 percent; petioles 0.8–3.1 cm long, 12–27 % length of lamina, prickles absent or present. *Upper leaf surface* green, prickles absent or present on midvein only, or occasionally on lateral veins also, prickles 0–7, straight, acicular, 8–12 mm long; stellate hairs distributed throughout, protostellae present, density sparse to moderate. Upper leaf surface ordinary stellae 0.2–0.6 mm apart, 0.4–0.7 mm across, stalks 0.1–0.8 mm long, lateral rays 4–8, porrect or ascending, central ray 0.8–1.5 times as long as laterals, central ray not gland-tipped; simple hairs absent; type 2 hairs present throughout, 0.05–0.1 mm apart. *Lower leaf surface* greenish white, white or grey; prickles absent or present on midvein only, 0–3, straight, acicular; stellate hairs dense or very dense; stellae 0.1–0.25 mm apart, 0.6–1.2 mm diameter, stalks 0.2–1.2 mm long; lateral rays 7 or 8, rays porrect; central ray 0.7–1.3 times as long as laterals, not gland-tipped; simple hairs absent; type 2 hairs present throughout, 0.05–0.2 mm apart. *Inflorescence* supra-axillary, cymose (pseudo-racemose), common peduncle absent or present, 0–7 mm long, rachis prickles absent or present, 7–11-flowered, with some bisexual and some male flowers. *Flowers* 5-merous; pedicels at anthesis 10–13 mm long, same thickness throughout, prickles absent or present. *Calyx* tube at anthesis 3–4 mm long; calyx lobes at anthesis deltate, 2.5–4 mm long; calyx prickles at anthesis absent or present, 0–5 per flower; stellate hairs very dense, yellow or brown or rusty, 0.6–0.7 mm across, stalks 0.1–0.5 mm long, lateral rays 7 or 8, central ray 0.8–1.2 times as long as laterals, not gland-tipped; simple hairs absent. *Corolla* purple, c. 14 mm long, shallowly lobed, inner surface glabrous. *Anthers* 4.0–4.3 mm long. *Ovary* with type 2 hairs only; functional style c. 8 mm long, protruding between anthers, with type 2 hairs only. *Fruiting calyx* lobes less than half length of mature fruit; prickles absent or present, 2–7 mm long. *Mature fruits* 1–4 per inflorescence, globular, 14–19 mm diameter, yellow or yellowish green, 1-locular (septum absent or incomplete); placenta stalked, anvil-shaped; mesocarp juicy, succulent; exocarp 0.7–1.1 mm thick; pedicels at fruiting stage 19–22 mm long, 1.1–1.5 mm thick at mid-point. *Seeds* pale yellow, 2.2–2.5 mm long. (Fig. 1).

Specimens examined: New South Wales. Port Macquarie, *collector unknown*, Oct 1892 (NSW); Killibakh Ck via Wingham, *T. Launders 16*, Oct 1983 (BRI, NSW); Woodside, Manning River, *Cameron s.n.*, Oct 1911 (NSW); 3.4 km along Mulligans Lane, near Burrell Creek, WSW of Taree, *A.R. Bean 23376*, Dec 2004 (BRI, MO, NSW).

Derivation of name: from the Latin *sulphureus* – sulphur yellow, in reference to the colour of the mature fruits.

Distribution: known from the Taree-Wingham area on the mid north coast of New South Wales. The 1892 specimen cited above gives the location merely as 'Port Macquarie', but the collection was probably made many kilometres from the town, as no suitable habitats are apparent close to Port Macquarie.

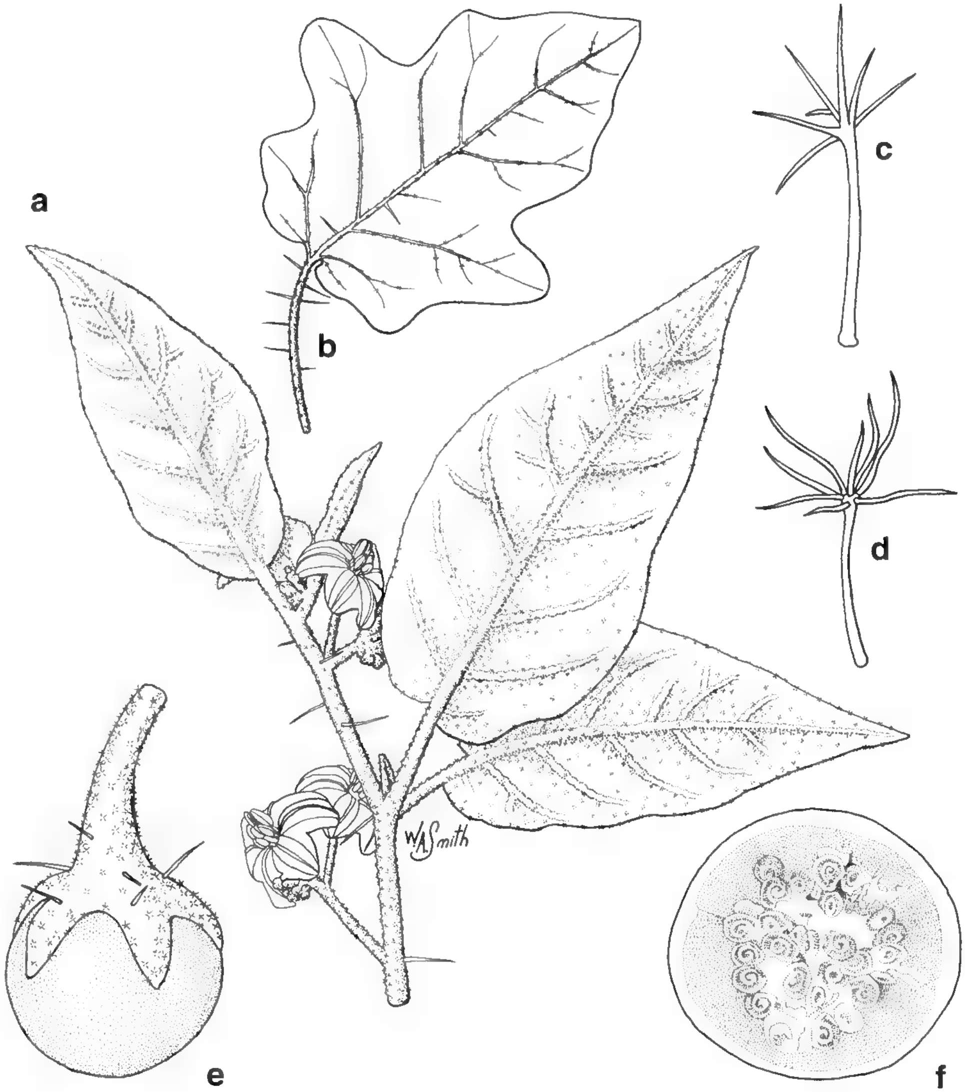

Fig. 1. *Solanum sulphureum*. a, flowering branchlet × 0.8; **b,** juvenile leaf × 0.6; **c,** a stellate hair from the upper leaf surface × 40; **d,** a stellate hair from the lower leaf surface × 40; **e,** a mature fruit with attached calyx × 1.5; **f,** transverse section of fruit × 2 (a, c, d from *Bean 23356*; b, e, f from *Bean 23376*).

Habitat: it inhabits sunny breaks in rainforest, rainforest regrowth on pasture land, or eucalypt forest with rainforest understorey. The soils are loams or clay-loams, shallow or deep. All collections have been from low altitudes (< 200 metres).

Conservation status: for the populations where the land use is cattle grazing, *S. sulphureum* is threatened by competition from aggressive pasture grasses, inevitably leading to a decline in population for the Solanum. My encounters with some local graziers indicated that they perceive any prickly plant to be a noxious weed, and that all 'native tomatoes' are poisonous and will result in the death of cattle. Hence the species is threatened by active destruction by humans. It not known from any Nature reserves or State Forests. A conservation status of Vulnerable (VU B2ab(iii,v); C1) is recommended, based on the Red List criteria (IUCN 2001).

Affinities: *S. sulphureum* is distinguishable from other Australian species by the entire ovate adult leaves (2.1–2.8 cm times longer than wide), the dense to very dense stellate hairs with stalks up to 1.2 mm long, the few-flowered cymose inflorescence, the calyx with few or no prickles and with stellate hairs 0.6–0.7 mm diameter, and the globose yellow fruits 14–19 mm diameter.

S. sulphureum is related to *S. brownii*, but differs by the adult leaves 2.3–5.8 cm broad with obtuse or cordate bases (1.4–2.9 cm broad, base cuneate or attenuate for *S. brownii*), the much larger stellate hairs on all vegetative parts of the plant, the presence of type 2 hairs on the branchlets and leaves, the anthers 4–4.3 mm long (5–6 mm for *S. brownii*), the yellow fruits (green or yellowish-green for *S. brownii*), and the seeds 2.2–2.5 mm long (2.6–3.1 mm long for *S. brownii*).

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Telopea 12(3) 443–444

Short Communication

Oryza nivara in Australia?

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This paper expands on notes provided on *Oryza nivara* S.D.Sharma & Shastry (1965) in the *Flora of Australia* Poaceae Volume 44A (Kodela 2009), where this species is treated as an excluded taxon.

Oryza nivara is part of the *O. sativa* L. complex and is related to *O. rufipogon* Griff. and *O. meridionalis* N.Q.Ng (in the AA genome group of wild rice). Sharma and Shastry (1965) describe how *O. nivara* differs from the closely related species *O. sativa* and *O. rufipogon*, but in a revision of the genus Duistermaat (1987) placed it in synonymy with *O. sativa*, whilst others have possibly confused *O. nivara* with *O. meridionalis*. There is also the possibility of the existence of intermediate forms between the various species.

Lu and Jackson (2004) distinguish *O. meridionalis* from *O. nivara* mainly on the basis of the spikelets, i.e. usually less than 2 mm wide in *O. meridionalis* and usually greater than 2 mm wide in *O. nivara*. The awn can also be distinctly longer in *O. meridionalis* (D. Vaughan, pers. comm.). However, where characteristics overlap there appear to be few other reliable morphological features to separate the species (P.G. Kodela, pers. obs., B.K. Simon, pers. obs. & comm.). There are also issues relating to the habit of the species where *O. rufipogon* (usually perennial), *O. meridionalis* (usually annual) and *O. nivara* (usually annual) may be influenced by a range of habitat factors such as wetter to drier conditions or deeper to shallower water.

Oryza nivara is reported to occur in India, Sri Lanka, Nepal, Bangladesh, Myanmar, Laos, Thailand, Cambodia, Vietnam, Malaysia and introduced into the U.S.A. and Australia (Vaughan 1994, Lu & Jackson 2004). The basis for a cited Northern Territory distribution of *O. nivara* (Sharma & Shastry 1965) is unknown, while a record of *O. nivara* from Queensland (Vaughan 1994, Anon. 2005) is based on *J.R.Clarkson 7320* from Red Lily Lagoon, Lakefield National Park (BRI, K, L, NSW) (D. Vaughan & B.K. Simon, pers. comm.). However, the Clarkson specimen and others from Australia with similar spikelet dimensions (i.e. > 2 mm wide) have been identified by most Australian experts as *O. meridionalis*. Further investigation, including study of Type material, is required to determine whether *O. nivara* occurs in Australia.

As well as the holotype of *Oryza nivara* (i.e. near Kandagarh, 16 km S of Raigarh, Madhya Pradesh, India, 15 Oct 1960, *S.D.Sharma 69*; CAL), Sharma and Shastry (1965) cite a number of paratypes, including *Pullen 1941* (LAE) from Papua New Guinea. Further investigation strongly suggests this is a typographical error for *Pullen 1641* (CANB71016, L, LAE), a specimen determined at CANB as *O. rufipogon* and described by Duistermaat (1987), who did not realise it was a paratype of *O. nivara*, as a possible local East Sepik form of *O. rufipogon* that has large spikelets with long sterile lemmas. This form has subsequently been referred to as a perennial *O. rufipogon* ecotype with

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similarities to *O. meridionalis* (Vaughan et al. 2008). Material of *Pullen 1941* was not located at LAE (R. Banka, pers. comm.); however, *Pullen 1941* held at CANB is a specimen of *Microtis* sp. (Orchidaceae) from Australia.

In conclusion, the status and placement of *O. nivara* is uncertain, especially in the Australian context where specimens appear to be difficult to distinguish from other AA genome *Oryza* species. There may well be introduced AA genome wild rice from Asia in Australia (brought in by birds or humans) and there appear to be intermediates and the possibility for hybrids that would complicate the current understanding of the taxa present (e.g. the status of *O. nivara*). The complex nature of *Oryza* in Australia warrants detailed study (D. Vaughan, pers. comm.).

Acknowledgments

I am very grateful for assistance and information provided by Australian Biological Resources Study (Canberra), Jenny Tonkin (Australian Botanical Liaison Officer at Kew 2006–2007), Bryan Simon (BRI), Peter Wilson (NSW) and Duncan Vaughan (FAO Regional Office for Asia and the Pacific, Bangkok, Thailand). Roy Banka (LAE) kindly checked the presence of relevant Pullen specimens held at LAE.

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Telopea 12(3) 445–446

Short Communication

Lectotypification of *Neckera hymenodonta* Müll. Hal. (Neckeraceae, Bryophyta)

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Müller (1851) described *Neckera hymenodonta* from Tasmania ("Van Diemen's Land"). In the protologue it was compared with "*N. pinnata*", which is here regarded as an orthographic error for *N. pennata* Hedw., since there is no taxon known with the former name. The name *N. hymenodonta* was synonymised with *N. pennata* by Sainsbury (1952), and it remained in taxonomic oblivion (cf. Beever et al. 1992, Fife 1995, Streimann & Klazenga 2002) until reinstated as a distinct species and described in detail as well as illustrated in line drawings by Ji & Enroth (2008). Some of the morphological distinctions between the two species are found in the peristome, as indeed noted by Müller (1851), but there are also more easily observed ones, such as the presence of paraphyllia in *N. hymenodonta* and their absence in *N. pennata* (Ji & Enroth 2008).

Carl Müller's personal herbarium was destroyed in Berlin in 1943 (e.g. Isoviita & Ochyra 1990). In connection with M.-C. Ji's PhD-thesis, which is a revision of *Neckera* in Asia and Australasia, type material of Müller's *N. hymenodonta* was sought in numerous herbaria worldwide, but unsuccessfully. In late 2008, two duplicates of the syntype material of *N. hymenodonta*, as cited in the protologue, were examined. As far as is known, they are the only remaining duplicates of the type material, so one of them is here designated as the lectotype. It should be noted that, nevertheless, both these specimens remain isotypes.

Neckera hymenodonta Müll. Hal., *Botanische Zeitung (Berlin)* 9: 564 (1851).

Type citation: [Australia, Tasmania] Van Diemen's Land, ad truncos arborum fruticeti densi infra Bek-river [sic!] prope Launceston. Coll. No. 746 [all specimens reported in Müller's (1851) work were collected in 1850 by Samuel Mossman].

Lectotype (designated here): "Neckera hymenodonta C. Muller On trees in a brushwood. S°. Esk River. Van Dieman's Land. Collected by Samuel Mossman. No. 746. 1850" (NY-Mitten!; Fig. 1).

Isotype: "Neckera hymenodonta C. Muller Bot. Zeit. 1851, p. 564. On trees amongst brushwood S. Esk River, Tasmania. Mossman 746" (NY-Mitten!; Fig. 2).

The duplicate selected as the lectotype has somewhat more material and has an original label of Samuel Mossman's herbarium. Both duplicates have William Mitten's herbarium stamp on the label. Clearly, the name "Bek-river" in the protologue is a misreading by Carl Müller of the hand-written name Esk, which is a river in NE Tasmania.

The newly discovered type material, although in good condition, does not add any new information of the morphological variation of *N. hymenodonta*, because it is quite a common species especially in New Zealand. Over thirty representative specimens were cited by Ji & Enroth (2008).

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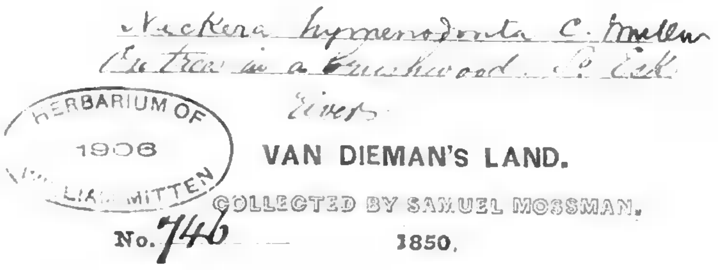
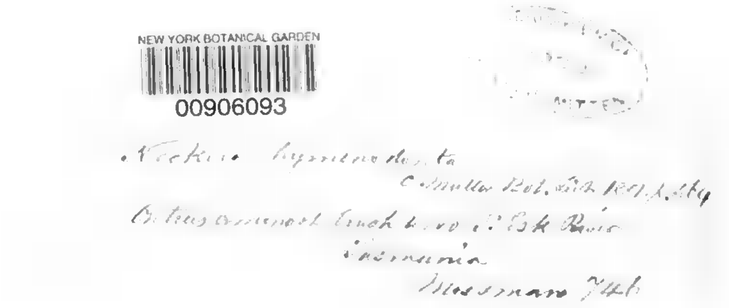

Neckera hymenodonta C. Muller
On trees in a brushwood. S. Esk
River

HERBARIUM OF
1906
WILLIAM MITTEN

VAN DIEMAN'S LAND.
COLLECTED BY SAMUEL MOSSMAN.
No. 746 1850.

Fig. 1. Packet label of lectotype of *Neckera hymenodonta* Müll. Hal.



Neckera hymenodonta
C. Muller Bot. Zeit. 1851, p. 564
On trees amongst brush wood S. Esk River
Tasmania
Mossman 746

Fig. 2. Packet label of isotype of *Neckera hymenodonta* Müll. Hal.

Acknowledgments

I thank William R. Buck (NY) who informed me of the presence of two duplicates of syntype material of *Neckera hymenodonta* and I thank the Director and staff of NY for making these materials available for study.

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Short Communication

Notes on *Cycas truncata* de Laub. and related matters.

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In December 2007, de Laubenfels published a new species of *Cycas* from the Philippines: *C. truncata*. He placed several *Cycas* names in synonomy under this new species: *C. inermis* Lour. ('nomen illeg., given in syn. *C. revoluta*'); *C. circinales* [sic] auct. non L; *C. rumphii* auct. non Miq.; *C. media* auct. non R. Br.; *C. silvestris* auct. non Hill and *C. riuminiana* auct. non Porte. In our opinion this paper did not deal adequately with a number of issues, the most significant of which was de Laubenfels' interpretation of de Loureiro's Latin description of *C. inermis*. We believe that de Laubenfels was in error when he stated that de Loureiro considered *C. inermis* to be a synonym of *C. revoluta*. This and several other matters arising from his 2007 publication are discussed briefly below.

Validity of the name *C. inermis* Lour., Fl. Cochinch., ed. 1, 2: 632 (1790).

C. inermis Lour. is a validly and legitimately published name in Edition 1 of Flora Cochinchinensis (1790) with an extant specimen housed by the BM that could reasonably be taken to be the Holotype (see Hill et al. 2004). Following the description of *C. inermis*, de Loureiro states:

"*Cycas circinalis. Jacq. Ac. Helver. tom. 8. pag. 59. tab. 2. Cycas revoluta. Thunb. Jap. pag 229. Olus Calapoides. Rumph. Amb. I. 1. cap. 20. tab. 20, 21, 22, 23, 24. Quamvis figurae Rumphianae aliquantulum differant, sicut etiam descriptiones Jacquini, & Thunbergii, puto pro diversis speciebus non habendas : nec etiam nostram, licet semper inermem invenerim, in quo ab illis dissidet. Ramosam nunquam vida, nec Monoicam.*"[1]

We contend that Loureiro's mention of *C. revoluta*, along with the two other species of *Cycas* known at the time (*C. circinalis* and Rumphius' "Olus Calapoides", now known as *C. rumphii*), was to compare and contrast the already-published cycads with his new species. In fact, Loureiro's Latin comments indicate that he considered that these three were not sufficiently distinct to justify them being separate species. He clearly states that his new taxon, *C. inermis*, differs from all of them by being consistently unarmed but does not specify the unarmed organs. The citation of the name *C. inermis* in synonymy with *C. truncata* by de Laubenfels renders the latter name illegitimate (Article 52.2, Ex. 2, McNeill et. al. 2006), even though the author of *C. truncata* considers the name *C. inermis* to be invalid.

Hill et al. (2004) applied the name *C. inermis* to a taxon occurring in the foothills of southern and central Vietnam. This is a widespread taxon in Vietnam, related most

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[1] Translation from the Latin: "Although the Rumphian figures [there are 5 cited] may differ by only a little, similarly I do not think the descriptions of Jacquin and Thunberg should be considered as separate species; not so ours [i.e., *C. inermis*], granted that I have always found it unarmed, in which [feature] it disagrees with them. I have never seen it branching, nor monoecious."

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closely to *C. macrocarpa* from Thailand and peninsular Malaysia. It is not considered to be part of or related to *C. silvestris* (regarded as an Australian endemic), or to occur in the Philippines. The illegitimacy of the name *C. truncata* thus leaves *C. inermis* (sensu Hill et al. 2004), *C. macrocarpa* (Hill & Yang 1999) and *C. silvestris* (Hill 1992, 1996) as valid taxa.

Does an undescribed taxon exist in Northern Luzon?

The description of *Cycas truncata* by de Laubenfels (2007) is problematic in a number of respects.

In the Latin description of *C. truncata*, de Laubenfels states "*Margines apicum microsporophyllorum dendatum* [sic] *ad 5 mm longum*". This does not fit with the dimensions given in the English description: "*Microsporophylls 15-22 mm wide, sharply truncated at the apex but raised slightly towards the center with a narrow sterile zone and with a spike10-23 mm long*". Furthermore, the previously published illustrations referred to by de Laubenfels do not adequately illustrate *C. truncata*. The Amoroso (1986) illustrations are apparently from a range of material (Amoroso 1986, table1), and the individual illustrations (Figs. 7-9, 27-30) are not linked to herbarium specimens. The Hill et. al. (2004) Fig. 17 refers to *C. inermis* sens. strict.

Apart from the designated type (*Merrill 3257*), no naturally occurring specimens are formally cited by de Laubenfels (2007), although one cultivated specimen is mentioned (*E.D. Merrill Species Blancoanae 855*). As a result, the logical conclusion one is forced to draw from de Laubenfels (2007) is that all of the previously cited material of *C. silvestris* (de Laubenfels & Adema 1998) falling within the geographic range now quoted for *C. truncata,* actually belongs to the concept of *C. truncata* presented. The majority of material cited as belonging to *C. silvestris* by de Laubenfels and Adema (1998) is here thought to represent several taxa from a number of countries (Table 1). Some specimens could not be located (Table 2). This leaves a 'core' of remaining specimens (Table 3), including the designated type of the name *C. truncata* (*Merrill 3257*). These specimens are from populations occurring in northern Luzon, a region where specimens cited and plants seen (Lindstrom et al. 2008) can be placed in either *C. riuminiana* or the recently described *C. zambalensis*. Our assessment of this core of remaining specimens (Table 3) is that they all fall into the character range of *C. riuminiana*.

This highlights the need for further taxonomic study, particularly in The Philippines. Although several new species have recently been enumerated (Madulid and Agoo 2005, Lindstrom et al. 2008), novelties may be anticipated, especially from the south-eastern Philippines (Mindoro and southern Luzon through to and including Mindanao). This area suffers considerable political unrest and substantial human impact (through clearing and farming), making the field work which would be required difficult.

Acknowledgments

Dennis Stevenson is gratefully thanked for his constructive comments on the manuscript, his translation of the Latin descriptions in Flora Cochinchinensis eds. 1 & 2 and for images of Merrill specimens held at NY. Peter Wilson is thanked for his helpful comments and his translation of the Latin description in Fl. Cochinch. Karen Wilson is also thanked for her Latin translation. We would also like to thank the following people for images of specimens: Jeremy Bruhl (while Australian Botanical

Table 1. Collections cited by de Laubenfels & Adema (1998) as *C. silvestris* but here thought to belong to other taxa.

Collection cited by de Laubenfels & Adema (1998)	**K.D. Hill determinavit**	**Collection Locality**	**Herbarium duplicates viewed by K.D. Hill**
Backer 50	*C. edentata*	Eile Krakatoa, Indonesia	L
v.BorssumWaalkes 523	*C. edentata*	Pulau Panaitan, Tg Manik, beach, West Java, Indonesia	BO, L
Chai SAN 29392	*C. edentata*	Mt Silamarea, Lahad Datu distr., Sabah, Malaysia	K ex SAN
Curran 3842	*C. curranii*	[type], Molinao River, on river bank, Palawan, Philippines	K, P
d.v.Leeuwin 1881	*C. rumphii*	Saleier group[?Salayar]: 2nd Saleier, zandige kust, South Sulawesi, Indonesia	BO
Edano 76373	*C. vespertilio*	Panagan River, Camarines Sur, southern Luzon, Philippines	BO, G, NY
Eyma 3727	*C. rumphii*	Tobelombang, Loewoek, Menado North Sulawesi, Indonesia	BO, L
Fosberg 32376	*C. rumphii* group?	E. coast of Babeldaob Isl., Palau Group, Palau	L
Kondo & Edano 36768	*C. vespertilio*	Gigantangan, Leyte, Philippines	L
Noerkas 481	*C. rumphii*	Tapalang, Celebes [South Sulawesi], Indonesia	BO, K, L,
Podzorski SMHI 2119	*C. curranii*	Narra, Mt Victoria, Trident Mining Co area, alluvial fan at base of ultrabasic mountain, Palawan, Philippines	L
Ramos & Edano 48953	*C. lacrimans*	[type] Davao, Mati, Mindanao, Philippines	BM, BO, NY, P

Table 2. Collections cited by de Laubenfels & Adema (1998) as *C. silvestris* but authors (KDH & LCS) unable to locate.

Cardona 23870
Curran 7381
Gressit 21 p.p.
Ramos 3281

Table 3. Collections cited by de Laubenfels & Adema (1998) as *C. silvestris* from the now designated type locality of *C. truncata*.

Collection cited by de Laubenfels & Adema (1998)	K.D. Hill determinavit	Collection Locality	Herbarium duplicates viewed by K.D. Hill
Curran 7513	*C. riuminiana*	Lamas [?Lamao], Luzon. Philippines	K
Merrill [Species Blancoanae] 855	*C. riuminiana*	cult Manila, Philippines	A, BM, BO, K, L, NSW, NY
Merrill 3257	*C. riuminiana*	Lamao R., Mt Mariveles, Luzon, Philippines (designated type of *C. truncata*)	BM, K, NY, P, US
Whitford 1235	*C. riuminiana*	Lamao River, Luzon, Philippines	K, NY

Liason Officer at K), Ciarán Moloney (NY), John Boggan (US) John Hunnex (BM) and Luc Willemse (L). Anders Lindstom is thanked for drawing our attention to the Encephalartos publication and Wynand van Eeden is also thanked for his assistance in sending us the pdf file of this article at short notice.

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De Laubenfels DJ & Adema F (1998) A taxonomic revision of the genera *Cycas* and *Epicycas* gen. nov. (Cycadaceae). *Blumea* 43: 351–400.

De Loureiro J (1790) *Flora Cochinchinensis*, vol. 2, edition 1: 632. (Ulyssipone [Lisbon]: Typis, et expensis academicis).

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Madulid DA & Agoo FAM (2005) A new species of *Cycas* (Cycadaceae) from the Philippines. *Blumea* 50(3): 510–522.

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Corrigenda - Telopea 12(1)

Lindstrom AJ, Hill KD and Stanberg LC. The genus *Cycas* (Cycadaceae) in The Philippines.

Page 136: selected specimens under *Cycas vespertilio* should read as follows.

Selected specimens: PHILIPPINES: Leyte: Gigantangan (? Hingatungan), *Kondo & Edaño PNH* ***36768***, **26** Mar 1957 (L).

Telopea 11(4)

Lindstrom AJ and Hill KD. The genus *Cycas* (Cycadaceae) in India.

Page 476:

Cycas sphaerica replaces *Cycas spherica.* Both spellings are acceptable, however, Roxburgh used the former in the protologue.

Telopea 12(4) 453–461

New species of *Eugenia* and *Gossia* (Myrtaceae: Myrteae) from Papua New Guinea

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Abstract

Two new species of Myrtaceae are proposed for Papua New Guinea: ***Eugenia craveniana*** N. Snow & Peter G. Wilson and ***Gossia yelana*** N. Snow & Peter G. Wilson.Each species is known from a single gathering. *Eugenia craveniana* is contrasted with *E. reinwardtiana* and *E. salomonica*, congeneric species also occurring in Papuasia. *Gossia yelana* represents the seventh confirmed species of the genus for New Guinea, but none of the species appear to be common there. Although fruiting material is needed to unambiguously place both species into their respective genera, a suite of other characters and the process of elimination allow us to propose them as new species. A conservation designation of Vulnerable is proposed for both species.

This paper represents Contribution No. 2009–012 to the Pacific Biological Survey.

Introduction

Ongoing curatorial work at Bishop Museum and the Royal Botanic Gardens, Sydney, has revealed two taxa that do not fit into currently recognised species limits among the flora of Papua New Guinea. The purpose of this paper is to propose one new species each for *Eugenia* and *Gossia*, discuss their distributions, and comment on morphologically similar species.

Methods

Collections of material were examined primarily from BISH, NSW, and in some cases from other institutions. Comparisons of the new taxa were made with congeneric species of the two genera known from Australia, New Caledonia, and New Guinea. Measurements were taken primarily from dried material, although fruiting or flowering material was rehydrated in boiling water. Although the description for each species is

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based on limited material, enough diagnostic characters are present to place each into its genus and distinguish it from congeners with reasonable certainty.

The species concept and terminology follow Snow (1997, 2008) and Snow et al. (2003). Geographical names follow Motteler (2006).

Eugenia craveniana N. Snow and Peter G. Wilson, ***sp. nov.***

Ab *E. reinwardtiana* marginibus foliorum undulatis et pedicellis plerumque glabris differt.

Type: Papua New G *41872* (holo BISH; iso A, BRI, CANB, K, LAE n.v., NSW).

Trees to c. 22 m high, d.b.h. c. 35 cm. Trunk fluted and twisted; crown rounded from erect branches. Outer bark mottled, light grayish-brown, smooth, peeling in irregular flakes; inner bark pinkish to straw colored, thin. Branchlets rounded, not winged, light grayish-brown, smooth, glabrous, lacking evident oil glands. Leaves dark green when fresh, concolorous to slightly discolorous when dry, surfaces matte, more or less evenly distributed along branchlets, coriaceous. Stipules consisting of 2–several very broadly and basally swollen, dark reddish hair-like structures (intermediate between type "B" and type "C" stipules [Snow et al. 2003: 6–7; see also Fig. 1i]). Petioles 2.1–3.2 mm, more or less round in transverse section, eglandular, splitting irregularly transversely with age, glabrescent with dibrachiate hairs. Leaf venation brochidodromous. Leaf blades (3.0–) 4.5–7.0 cm × (1.1–) 2.0–3.8 cm, narrowly elliptic to obovate; base cuneate, apex obtuse to acute; secondary and tertiary veins raised above and below; margins undulate; upper surface bearing sparse dibrachiate hairs, becoming glabrous, oil glands small, barely visible, midvein narrowly but steeply raised in its center but flat on the edges; lower surface glabrous, oil glands small, barely visible, intramarginal vein prominent, c. 0.5 mm from edge at midpoint of leaf blade. Inflorescence terminal or mostly lateral, of one to several solitary flowers arising from highly condensed short shoots and thus appearing fasciculate (Fig. 2). Anthopodia and metaxyphylls (sensu Briggs and Johnson 1979) absent. Peduncles 5.5–14 mm × 0.5–0.7 mm, ascending to erect, glabrous or bearing sparse and short dibrachiate hairs distally below base of hypanthium, more or less rigid, smooth to faintly striate. Bracteoles 2, 0.4–0.6 mm × ≤ 0.3 mm, narrowly triangular, opposite to disjunct opposite, ascending, much shorter than hypanthium, early caducous, shortly but irregularly hairy apically. Hypanthium c. 1.3 mm long, obconic, hairs dibrachiate and sparse; smaller oil glands common, round, larger oil glands of irregular size and shape and somewhat pustulate (these possibly representing fungal growth). Calyx lobes 4, 0.7–1.3 mm, fused below but distinct in bud, broadly rounded, obtuse, moderately to densely sericeous above and conspicuously ciliate on margins, sparsely sericeous below. Petals 4, 3–3.5 mm, widely obovate to oblate, moderately sericeous above, glabrous below, oil glands lacking. Staminal disk 1.4–2 mm diameter, glabrous. Stamens 40–50, multiseriate; filaments 1–2.5 mm long, most with 1–several light elliptic glands; anthers c. 0.5 mm, globose, basi- or sub-basifixed, connective eglandular. Styles c. 3.5 mm, glabrous, prominently glandular. Locules 2, placentation axile, placenta capitate, ovules 5–7 per placenta. Fruit unknown. Figure 1.

Geographical distribution. The species is known only from the type gathering. The reliability of the coordinates given on the collection label (10°10'S, 148°20'E) is uncertain. If the collection was made near Mori Station, it likely is closer to 10°06'S, 148°30'E. Geologically, this part of the Papua Peninsula appears to fall somewhere near the boundaries of the western part of the Kutu terrane and the eastern edges of

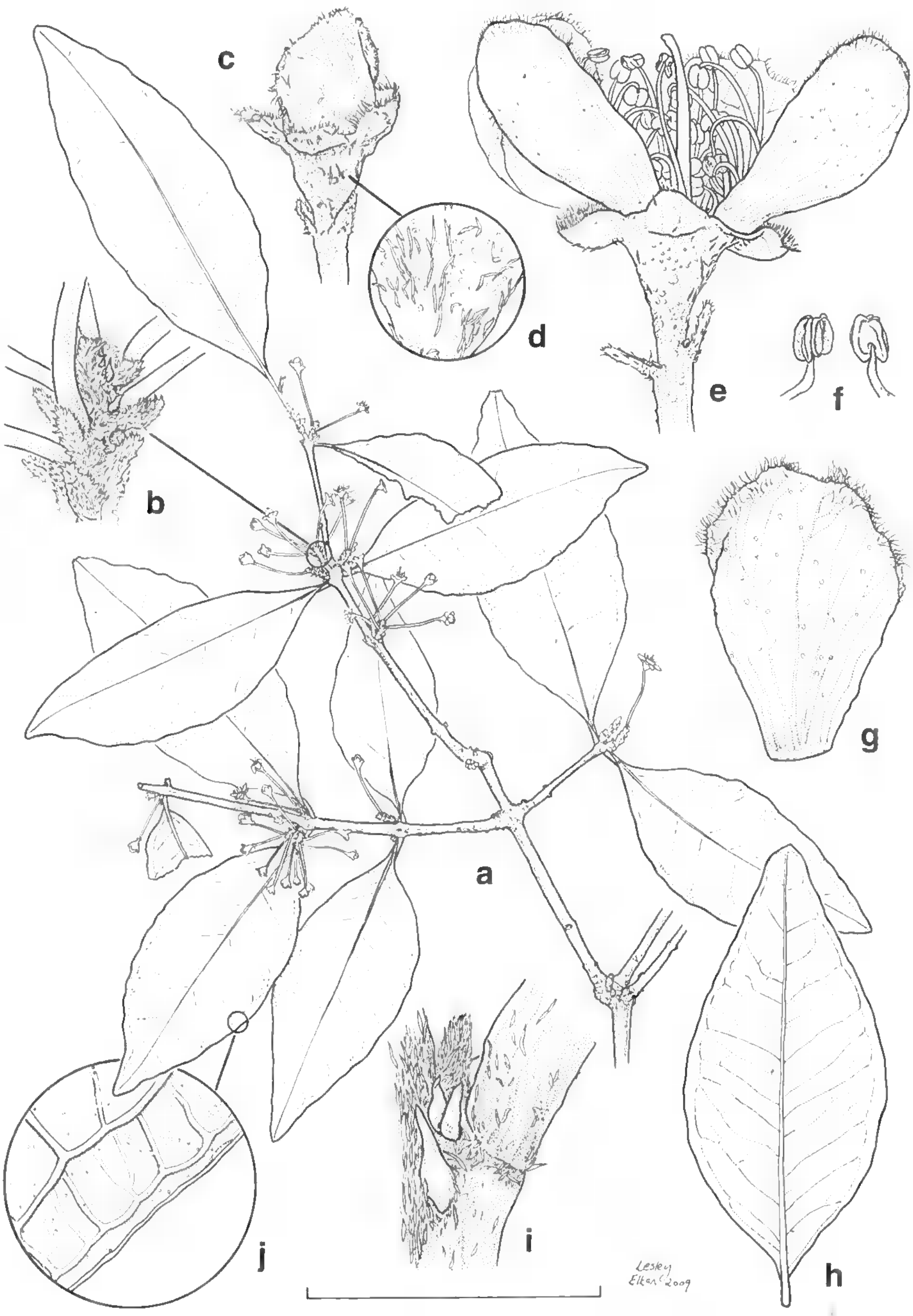

Fig. 1. *Eugenia craveniana*. **a**, habit; **b**, short, bracteate flowering shoot; **c**, flower bud; **d**, detail of hypanthium showing dibrachiate hairs; **e**, open flower; **f**, stamen; **g**, petal; **h**, leaf showing venation; **i**, detail of node showing distinctive stipules; **j**, detail of intramarginal venation. (all from *Henty & Lelean NGF 41872*). Scale bar: a = 50 mm; b, c, e, j = 4 mm; d, f, i = 2 mm; g = 3 mm; h = 30 mm.

the Port Moresby terrane, the transitional area of which is poorly known (Pigram & Davies 1987).

Phenology. Flowering in early February; probably fruiting late February onwards.

Habitat and ecology. The specimen label indicates the locality is among limestone hills at c. 245 metres (800 feet on label).

Conservation. Given that *Eugenia craveniana* is known only from the type gathering, and that designations of Data Deficient (IUCN 2005) are probably inappropriate for remote areas in the tropics, and considering the recommendations of Callmander et al. (2005), we propose a designation of Vulnerable (D2) given the restricted area of occupancy (less than 20 km^2) and limited number of collections (fewer than 5).

Etymology. The specific epithet honours our colleague Lyn A. Craven (b. 1945) of the Australian National Herbarium (CANB), a longtime student of Myrtaceae (e.g., Hartley and Craven 1977; Craven 1980, 1987a,b, 2001, 2003, 2006; Craven & Jones 1991; Craven et al. 2004; Biffin et al. 2006), a previous collector of plants in Papua New Guinea, and one who has assisted the authors in their studies of Myrtaceae.

Comparison with other species in the region. The undulate leaf margin of *E. craveniana* is not shared with other species of *Eugenia* from Papuasia. Its twisted and fluted main bole is shared with some specimens of *E. salomonica* (White 1951), although not all specimens of the latter at BISH are reported to have buttresses or fluted trunks. The one known locality of *E. craveniana* is on the Australian craton.

Fig. 2. *Eugenia craveniana*. Close up of short, bracteate flowering shoots from holotype.

In contrast, the confirmed range of *E. salomonica* is from islands located north of the New Britain Trench or east of the North New Hebrides Trench. As currently known, *E. salomonica* ranges from Mussau Island of the St. Matthias group (e.g., *D. Lepofsky 437* at BISH) and Bougainville of Papua New Guinea (White 1951) to the Solomon Islands, where it is known on Santa Isabel (White 1951) and the small island of Tömotu Noi of the Santa Cruz (= Nendö ; see Motteler 2006: 46–47) Islands (e.g., *J. M. Powell 19865* at BISH). Its occurrence in New Guinea was overlooked by Govaerts et al. (2008).

Notes. *Eugenia craveniana* is tentatively placed in *Eugenia* because of its abbreviated bracteate inflorescence of uniflorous flowers, which are 4-merous, its bilocular ovary and peltate placenta with relatively few ovules, and dibrachiate hairs, all of which characterise a large percentage of species in *Eugenia* (excluding *Hexachlamys* O. Berg) (e.g., Landrum & Kawasaki 1997). The species resembles some in *Gossia* but does not match any species of *Gossia* known from Australia, New Guinea, or the Solomon Islands (Snow et al. 2003; Snow 2005, 2006). Examination of mature fruit would enable a definitive generic placement to be made, but because dibrachiate hairs are uncommon among baccate genera in Australia and New Guinea, and other characters of the flower are not aberrant in *Eugenia* (excluding *Hexachlamys*), we are confident placing the new species in *Eugenia* pending the hopeful re-collection of the species in fruit.

The stipule-like structures dry to a deep maroon color. On emerging branchlets they are scale-like and somewhat rounded. On older branchlets, and in the axils of bracteoles, the bases of the hair-like projections are notably swollen ("type B" stipules in Snow et al. 2003). This stipule type does not occur on *E. reinwardtiana* or *E. salomonica*.

Gossia yelana N. Snow and Peter G. Wilson, ***sp. nov.***

Gossia salomonensi similis sed foliis ellipticis (vice ovatis) tantum breviter acuminatis, petalis maioribus, bracteolis multo latioribus non caducis, axe florifero breviore contracto bracteas angustiores praedito differt.

Type: Papua New Guinea: Papuan Islands: Rossel (Yela) Island, Nanga Bay, 11°20'S, 154°10'E, altitude sea level, 11 Oct. 1966, *A. Gillison NGF25378* (holo BISH; iso BRI, CANB, LAE n.v., NSW).

Trees to c. 4.5 m high. Bark of main stem smooth, brownish-grey. Branchlets rounded, wingless, light brownish-gray, smooth, sparsely sericeous becoming glabrous, oil glands sparse and small. Petioles 4–5 mm long, channeled above, somewhat glandular when young, glabrous at maturity. Leaves coriaceous, concolorous or slightly discolorous, surfaces matte or slightly glossy above. Leaf venation brochidodromous. Leaf blades 4–60 × 18–25 mm, elliptic; base cuneate, apex acute to obtusely acuminate, margin flat to slightly revolute, surface flat to slightly undulate; adaxial surface glabrous, oil glands slightly raised, midvein impressed proximally, becoming flush distally; abaxial surface glabrous, oil glands slightly raised, secondary and tertiary veins visible but thin, intramarginal vein faint, 0.5–1.5 mm from edge of margin at midpoint of blade. Inflorescence of (1–)2–4 monads borne in the axils of bracts on short brachyblasts (highly contracted, shortly-bracteate axes), either at the shoot apex or on older wood below the leaves; anthopodia absent, metaxyphylls absent. Peduncles (7.5–)12–17 mm long, rigid, straight to slightly curved, glabrous to very sparsely sericeous. Bracteoles 2, (0.9–)1.1–1.4 × 0.9–1.3 mm, triangular to broadly ovate, more or less erect, rigid, sparsely sericeous and shortly ciliate marginally (hairs bending irregularly). Hypanthium 1.3–1.7 mm, obconic, oil glands sparse, sparsely sericeous. Calyx lobes 4, 1.1–2.1 × 2.1–3.2 mm, broadly rounded, apex obtuse, slightly imbricate at base, 2 outer lobes somewhat larger than 2 inner lobes, glabrous to very sparsely sericeous. Petals 4, 5–6.5 mm × 2.5–3.5 mm, not clawed, sparsely ciliate on margins, oil glands common. Staminal ring 0.7–1 mm wide, c. 2.8 mm in diameter, shortly villous. Stamens >100, multiseriate, inflexed in bud; filaments up 3–7 mm long; anthers 0.5–0.7 mm, globose to subcylindrical, dehiscence evidently latrorse, dorsifixed towards the base of the connective, which bears a single (often obscure) apical gland. Styles 5–6 mm, glabrous, narrowing to a scarcely capitate stigma. Ovary 2-loclular, placentation axile, placenta capitate, ovules (as far as seen) 12 or more per placenta. Fruit unknown. Figure 3.

Geographical distribution. *Gossia yelana* is known only from Nanga Bay on Yela Island (= Rossel Island [Motteler 2006]). No indication is given of its relative abundance on the collection label. Yela Island is located in the Solomon Sea, and is a geological outlier of the Owen Stanley terrane, which docked with the rest of the New Guinea Peninsula approximately 15 mya (Pigram & Davies 1987).

Habitat and ecology. The herbarium label data indicates *Gossia yelana* was collected from shoreline vegetation and is a low-growing tree 15 feet [c. 4.5 meters] high, associated with *Intsia bijuga* (Colebr.) Kuntze (Fabaceae).

Phenology. Flowering in early February; probably fruiting late February onwards.

Conservation. Given that *Gossia yelana* is only known from a single gathering, and following the rationale above for *Eugenia craveniana,* we propose a conservation status of Vulnerable until more information is available.

Etymology. The specific epithet refers to its occurrence on Yela Island, the alternate name for Rossel Island.

Comparison with similar species. *Gossia yelana* resembles *G. salomonensis*, which is restricted to the small island of Ghizo, New Georgia Group (8°04'36"S, 156°47'35"E). However, *G. salomonensis* has long-acuminate, ovate to narrowly ovate leaves, much narrower, caducous bracteoles and much broader bracts along its brachyblasts (short, flowering shoots). In addition, the brachyblasts of *G. salomonensis* are much less condensed than those of *G. yelana*, in which the bracts are spaced more densely. *Gossia yelana* and *G. salomonensis* also appear to occupy different habitats; the former occurring in coastal forests slightly above sea level, whereas the latter is known only from ridge top forest (c. 165 m) in well drained primary forests, where it may grow to over 9 m tall (Scott 1980).

Notes. The collector's notes indicate that in fresh material the leaves are reportedly shiny green and conspicuously punctate, whereas the petals are white.

The description of *Gossia yelana* brings to seven the number of species in the genus known to occur in New Guinea (*G. eugenioides*, *G. floribunda*, *G. longipetiolata*, *G. randiana*, *G. scottiana*, *G. versteeghii*) (Snow 2006). Unlike some species of *Gossia* from Australia (Snow et al. 2003) and New Caledonia (Snow in prep.), none of the species from smaller islands in the region (*G. aneityensis*, *G. salomonensis*) appear to be ecologically common.

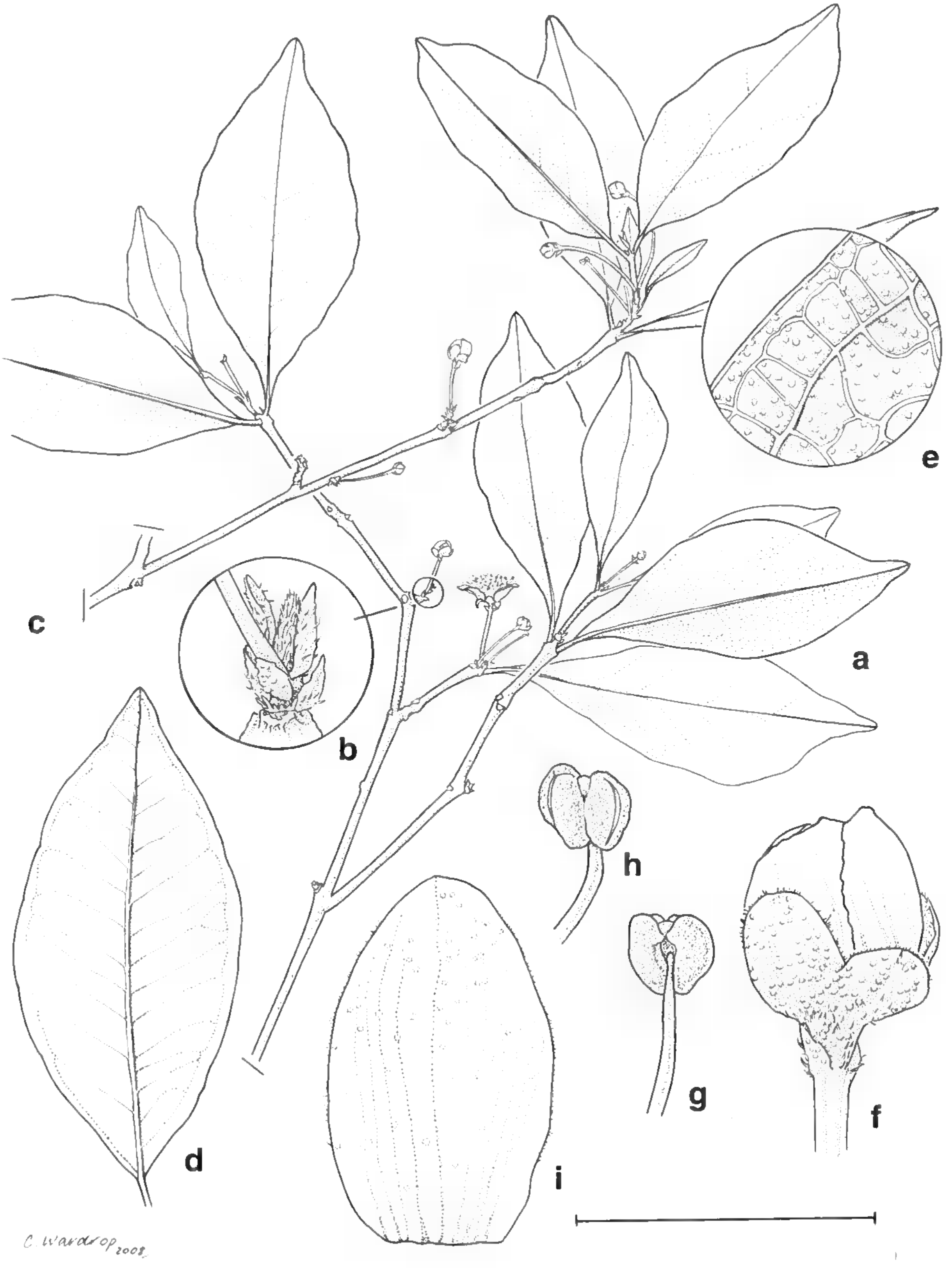

Fig. 3. *Gossia yelana*. **a**, habit; **b**, short, bracteate flowering shoot; **c**, habit; **d**, leaf showing venation; **e**, detail of intramarginal venation; **f**, flower bud; **g**, **h**, stamen, front and back; **i**, petal. (all from *Gillison NGF25378*). Scale bar: a, c = 50 mm; b = 5 mm; d = 30 mm; e = 4 mm; f, i = 6 mm; g, h = 0.2 mm.

Acknowledgments

Our thanks to the curators at BRI and CANB for the loan of relevant specimens of Australasian Myrtaceae. Peter Ashton (A) confirmed the distribution of *Eugenia* in Malesia based on his knowledge of the genus; Emily Wood (A) provided a digital image of an isotype from Harvard; John Dawson (WELTU) confirmed that the new species of *Eugenia* does not match known material from New Caledonia. Mahalo to Arnold Hori (BISH) for capturing the digital image, and to Lesley Elkan and Catherine Wardrop for the excellent illustrations. We thank Eve Lucas (K) and Barry Conn (NSW) for their constructive comments.

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Scutellaria slametensis (Lamiaceae), a new species from Central Java, Indonesia

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Abstract

The new species ***Scutellaria slametensis*** Sudarmono and B.J.Conn (Lamiaceae) from Gunung Slamet, Jawa Tengah, Indonesia is here described and illustrated. This species is morphologically similar to *S. javanica*, but can be distinguished by its pale blue corollas (cf. dark purple in *S. javanica*) and leaves that are longer and shortly attenuate at base (cf. broadly cuneate in *S. javanica*).

Introduction

The genus *Scutellaria* L. (Lamiaceae), a member of the subfamily *Scutellarioideae* (Paton in Harley et al. 2004), is subcosmopolitan, but poorly represented in moist tropical lowlands. The genus can be easily recognised by its distinctive calyx, with a protrusion, or 'cap' on the adaxial (upper) lobe. It consists of about 360 species (Li & Hedge 1994; Paton 1990; Hsieh & Huang 1995; Paton in Harley et al. 2004). The most recent account of the genus for the region was by Keng (1978) who recognised three species for Malesia, namely, *S. discolor* Colebr., *S. indica* L. and *S. javanica* Jungh. Based on leaf characters and density of glandular trichomes, he recognised two varieties within *S. discolor* (namely, var. *discolor* and var. *cyrtopoda*) and within *S. javanica* he recognised four varieties (namely, var. *javanica*, var. *luzonica*, var. *russeliifolia* and var. *sumatrana*). Recent plant collections from Gunung Slamet, Jawa Tengah, Indonesia, revealed an undescribed species of *Scutellaria*.

Terminology follows Conn (1984). Inflorescence terminology follows Briggs and Johnson (1979), as modified by Conn (1995). Since the herbarium of Kebun Raya Indonesia, Bogor has not been officially registered in *Index Herbariorum* (Holmgren and Holmgren (1998+), the acronym 'KRB', referring to 'Kebun Raya Bogor,' is used in this paper.

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Scutellaria slametensis Sudarmono and B.J.Conn ***sp. nov.***

S. javanica *Jungh. affinis sed foliis longioribus (plerumque 50–155 mm) ovatis vel anguste ovatis, lamina basi breve attenuata, corolla lavandulacea differt.*

Holotype: Indonesia: Jawa Tengah: Gunung Slamet Post III, Baturraden climbing track, Purwokerto, *Sudarmono MN18SLA and Sumanto*, 29 May 2008, (BO1877916); isotypes: KRB, NSW805395.

Perennial herb, 0.4–1.5 m high. Stem erect, quadrangular, often with internodes laterally grooved, densely hairy (200–280 hairs/mm^2), hairs eglandular, minute, 0.02–1 mm long, straight or slightly curved distally, patent to slightly antrorse or slightly retrorse (particularly on older branchlets); densely glandular (up to c. 160 glands/mm^2), more plentiful on younger growth, glands c. 0.02 mm diameter, sessile, yellow to red. Leaves decussate; petiole (10–)18–25 mm long; lamina ovate to narrowly ovate, (46–)50–155(–186) mm long, 25–40(–45) mm wide, base shortly attenuate, margin bluntly and shallowly crenate (blunt teeth 5–8, sometimes as many as 10), apex acuminate, chartaceous, moderately hairy (especially on venation of abaxial surface), hairs as for branchlets, sparsely glandular (c. 6 glands/mm^2), glands as for branchlets. Inflorescence botryoidal, densely floriferous, narrowly conical, becoming more cylindrical in fruit, 40–140 long, 18–130 mm diam.; flowers opposite, 2 per node; bracts sessile, ovate to narrowly ovate, (1.5–)2–4 mm long, 1–1.2 mm wide, base attenuate, margin entire, apex acuminate, enclosing buds then becoming deflexed in flower, persistent through flowering stage, moderately to densely hairy, hairs 0.1–0.15 mm long, antrorse, densely glandular; uniflorescence monadic; pedicel (3–)4–5 mm long, held at 35°–55° to rachis; prophylls (subtending single flowers) linear or linear-ovate, 5–8 mm long. Calyx green; tube 1–2 mm long, outer surface moderately hairy and glandular (hairs and glands as for branchlets); scutellum semi-circular, spreading, 1–1.5(–2.2) mm long dilated to 3 mm long in fruit; lobes 0.7–1.5 mm long, abaxial lobe slightly longer than adaxial lobe, hairs up to 0.4 mm long, glands occasional, red. Corolla white basally, pale blue to sometimes pale purple distally, 11–18(–23) mm long; outer surface hairy and glandular; tube basally very narrow and parallel-sided for 3–5 mm, then curving sharply upwards and remaining parallel-sided for 4–6 mm and then broadening distally for 5–7 mm, abaxial outer surface densely hairy, more densely hairy towards adaxial outer surface, hairs up to 0.2 mm long, patent multicellular, glandular; inner surface densely hairy near base of style (distal to corolla 'elbow', hairs 0.5–1.5 mm long, patent or slightly antrorse, unicellular, non-glandular, apex rounded), sparsely to moderately hairy distally (hairs 1–2 mm long, antrorse, multicellular, non-glandular, apex tapering to subacute); abaxial (anterior) lobes almost circular to broadly ovate, 4–6 mm long, 4–6 mm wide, base slightly cordate, margin distally 2-lobed (sinus 0.5–1 mm long); lateral lobes broadly triangular to oblong, 4–4.5 mm long, c. 2 mm wide; adaxial (posterior) lobes boat-shaped, 5–7(–9) mm long, 3–4 mm wide, partially enclosing stamens. Stamens included to slightly exserted; adaxial (posterior) pair basally adnate to corolla for 10–14 mm, curved upwards sharply; abaxial (anterior) pair adnate for 6–8 mm, curved upwards more gradually than adaxial stamens; filaments 8–9 mm long, glabrous, except for a few hairs basally; anthers versatile, c. 1 mm long, margin of locule stomium densely hairy (hairs 0.2–0.3 mm long). Disk 0.8–1 mm high, 1–1.3 mm diam., densely glandular (glands hemispherical, c. 0.1 mm diam.); gynophore 0.3–0.5 mm long; ovary 0.5–0.8 mm long, 0.8–1 mm diam., densely glandular (as for disk); style 20–23 mm long, glabrous; stigma 0.7–1 mm long. Fruiting calyx with tube 3–7 mm long, somewhat ventrally gibbous, lobes patent or sub-patent, becoming

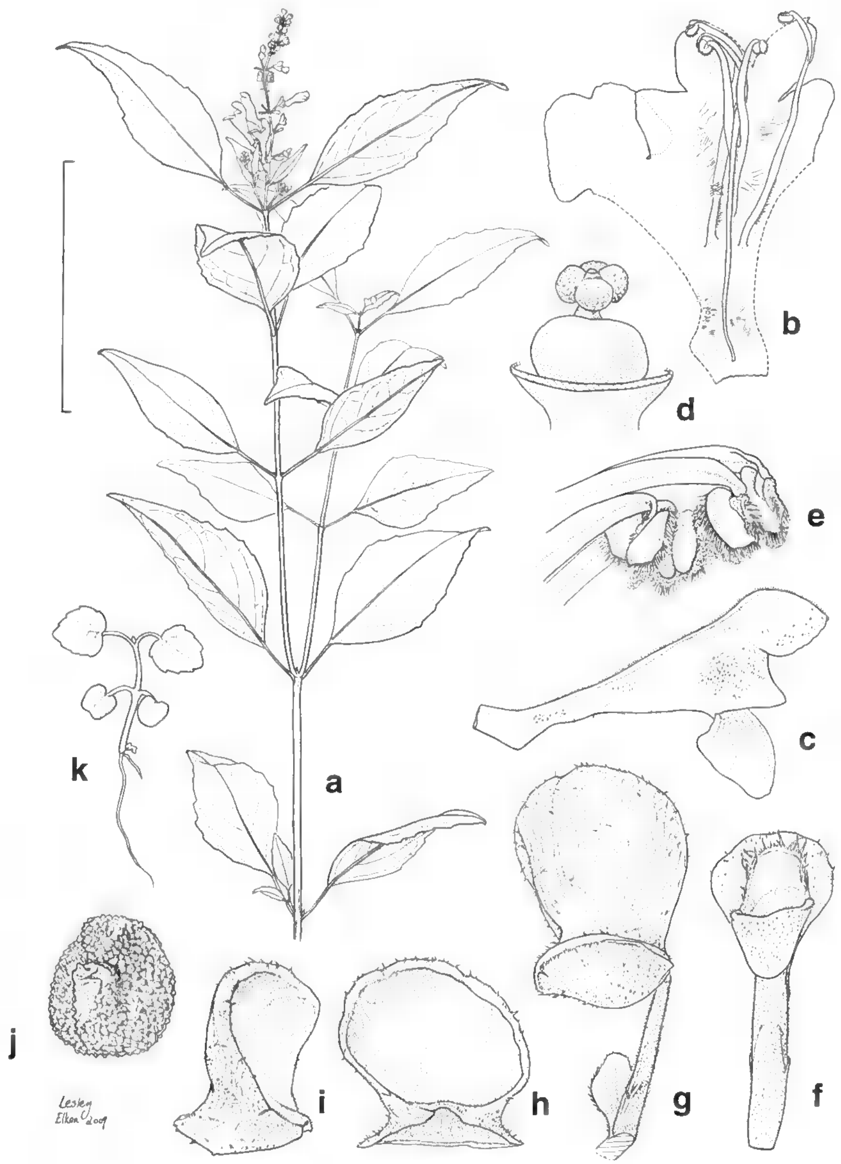

Fig. 1. *Scutellaria slametensis* **a,** flowering branchlet; **b,** open corolla showing androecium, style and stigma. Note: adaxial corolla lobe dissected and flattened to illustrate anthers; **c,** corolla (lateral view); **d,** detail of disk, gynophore and ovary, with style removed; **e,** detail of dehisced anthers and distal part of filaments, with corolla removed; **f,** developing calyx (ventral view) with scutellum dorsal to adaxial calyx lobe, including prophylls on pedicel; **g,** three-quarter view of mature calyx with lobes closed to protect developing seeds, scutellum strongly developed, with subtending leafy bract on pedicel; **h,** dehisced adaxial calyx lobe and scutellum (dorsal view); **i,** dehisced adaxial calyx lobe and scutellum (lateral view); **j,** detail of seed (adaxial view); **k,** seedling showing cotyledons and first true leaves, all from *Sudarmono MN18SLA & Sumanto* (NSW). Scale bar: a = 100 mm; b & c = 15 mm; d, e & j = 3 mm; f–i = 8 mm; k = 30 mm.

thicker and more rigid with age, variable in length; scutellum (dehiscent with adaxial lobe) 4–5.5 mm long. Mericarps black or dark brown, broadly ellipsoid and slightly flattened, 1–1.5 mm long, darkly gland-dotted, not mucilaginous, lacking hooked tubercles. Fig. 1.

Distribution: only known from Gunung Slamet, Jawa Tengah, Indonesia.

Habitat: this species occurs in hill and submontane forests, in open shady areas along walking trail, in clay soils; at elevation of about 800–2400 m.

Other specimens examined: Indonesia: Jawa Tengah: Purbalingga Regency: Gunung Slamet: *Hoover, Hunter, Wiriadinata and Girmansyah s.n.*, 14 March 2004 (BO1693907); Gowok forest, *Hoover, Hunter, Wiriadinata and Girmansyah s.n.*, 14 March 2004 (BO1705600); Brebes Regency: Gunung Slamet Block Sakub, Kaligua, Pandansari village, *Sudarmono MN03SLA and Sumanto*, 27 May 2008 (BO1877957, KRB, NSW805394).

Conservation status: the conservation status of *Scutellaria slametensis* is Data Deficient but may prove to be Vulnerable because of its small number of populations and potentially few individuals.

Etymology: the epithet 'slametensis' refers to the name of the mountain (Gunung Slamet) from where the type material was collected.

Notes: *Scutellaria slametensis* is a short herb, 0.4–1.5 m high, similar in height to that of *S. javanica* (up to 1 m high), whereas *S. discolor* is shorter (0.2–0.4 m high) and *S. indica* is larger (0.8–2.8 m high). In *Scutellaria slametensis*, flowering coincides with shoot expansion (pleonanthic *sensu* Hallé *et al.* 1978), typical of species of this genus and many other members of the Lamiaceae. The blastotelic inflorescence (*sensu* Briggs and Johnson 1979) is botryoidal consisting of monadic uniflorescences. Each node of the inflorescence of *S. slametensis* has a pair of flowers similar to *S. indica* and *S. javanica*, whereas *S. discolor* has 2–4 flowers per node. The surface of the mericarps of *S. indica*, *S. javanica* and *S. slametensis* all lack the acuminate tubercles, which are tipped by a whorl of hooks, that occur in *S. discolor*. Hooked tubercles also occur on the mericarp surface of *S. austrotaiwanensis* T.H.Hsieh & T.C.Huang (1997) from Taiwan. *Scutellaria slametensis* has narrowly ovate leaves (similar to *S. javanica*), with margin bluntly crenate (cf. *S. javanica* crenate to remotely serrate) and both have bluish corollas. *Scutellaria slametensis* has pale blue corollas, whereas *S. javanica* mostly have dark blue to dark purple corollas. *Scutellaria discolor* and *S. indica* have more rounded leaves than the above species, with the margin crenate to coarsely crenate, and the corollas are mostly more darkly coloured, but, vary from pale blue to purple. This very distinctive species remains poorly known. Sterile material of *S. slametensis* is likely to be difficult to distinguish from *Orthosiphon aristatus* (Lamiaceae) because both habit and leaves are superficially similar.

Note: The pedicel is here regarded as the a_1 axis plus anthopodium (refer Conn 1995).

Key to Species in Indonesia

1a. Distal flowers often in spiral-like clusters or almost so, 2–4 flowers per node, radially spreading; inflorescences terminal; mericarps with acuminate tubercles terminating in a ring of hooks; bracts minute .... ***S. discolor***

1b. Flowers opposite, 2 per node, erect to suberect; inflorescence lateral or terminal; mericarps lacking hooked tubercles; bracts leaf-like 2

2a. Herb up to 0.3(–0.4) m high, usually prostrate, often unbranched; leaves mostly radical, broadly ovate to rounded or reniform, base truncate to cuneate, often cordate; flowers with pedicels almost patent to rachis .... ***S. indica***

2b. Herb 0.4–1.5 m high, usually erect and branched; leaves spaced along stem, narrowly ovate, base shortly attenuate or broadly cuneate; flowers with pedicels obliquely erect to rachis 3

3a. Leaves with lamina 20–40(–60) mm long, 15–20 (–35) mm wide, base broadly cuneate, apex caudate-acuminate; corolla dark purple, 14–31 mm long .... ***S. javanica***

3b. Leaves with lamina (46–)50–155(–186) mm long, 25–40(–45) mm wide, base shortly attenuate, apex acuminate; corolla distally pale blue to pale purple, 11–18(–23) mm long .... ***S. slametensis***

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Typification of some names in *Eucalyptus* (Myrtaceae), Part 2

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Abstract

Eleven names in *Eucalyptus* (Myrtaceae) are here typified, and the typification is clarified or corrected for a further three names. The names dealt with in this paper include *E. tessellaris* var. *dallachiana, E. brownii, E. cambageana, E. cloeziana, E. dawsonii, E. intertexta, E. malacoxylon, E. melanophloia, E. morrisii, E. nova-anglica, E. raveretiana, E. rudderi, E. thozetiana* and *E. viridis.* The species involved are all indigenous to Queensland or New South Wales. A discussion of relevant type specimens is provided, together with other nomenclatural notes.

Introduction

There remain significant numbers of accepted *Eucalyptus* species names that have never been formally typified. The first paper in this series (Bean 2009) dealt with the typification of 15 current names in *Eucalyptus.* This paper deals with a further 14 names, one of which is now referable to *Corymbia* K.D.Hill & L.A.S.Johnson. Of these, 11 are typified, while for a further three names the typification is clarified or corrected. Nomenclatural information offered by Brooker et al. (1984), Chippendale (1988), Hill (2002-04) and Slee et al. (2006) is discussed, especially where it differs from the view expressed here.

The species treated herein are all indigenous to Queensland or New South Wales, and are arranged alphabetically by currently accepted name.

Typification

Corymbia dallachiana (Benth.) K.D.Hill & L.A.S.Johnson, Telopea 6: 451 (1995); *Eucalyptus tessellaris* var. *dallachiana* Benth., Fl. Austral. 3: 251 (1867).

Type citation: "Queensland, Bowman; Rockhampton, Dallachy". **Lectotype** (Blake 1953, p. 223): "Dallachy 171, from Rockhampton (MEL)" (**lecto** MEL1611091 here designated; isolecto: MEL1611092).

Blake (1953) chose "Dallachy 171, from Rockhampton (MEL)" as the lectotype. There are two sheets at MEL with original labels in Dallachy's handwriting, each with the

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number "171". On each sheet there is a separate blue label in Mueller's handwriting stating "Eucalyptus tessellaris FvMueller var. dallachiana/ Rockhampton". In accordance with Article 9.15 (McNeill et al. 2006), Blake's initial lectotypification is here restricted to MEL1611091.

While the letter "B" written on the corner of the blue labels is confirmation that Bentham saw these sheets, the specimens were cited by Bentham in the protologue and are original material regardless of whether he saw them or not (McNeill et al. 2006, Article 9.2, Note 2).

Dallachy's handwriting is difficult to decipher, but the locality appears to be "Mt Archer", a mountain close to Rockhampton. In writing that is more legible he stated "had to cut down the tree/ I was sorry to do it".

Hill and Johnson (1995) chose a specimen at K as the lectotype. They cited the following "Dallachy 109 (lecto: K; isolecto: MEL)". Slee et al. (2006) also accepted this specimen as the lectotype. The number "109" appears on the label of the specimen at K, written by a person unknown, but certainly not by Dallachy. The origin and meaning of this number is obscure, and none of the sheets at MEL bears it (but there is another Dallachy specimen from Rockhampton, collected 5 January 1866, that lacks any number – MEL 707570). In any event Hill and Johnson's lectotypification is not valid because S.T. Blake had earlier chosen a different gathering as the lectotype. Hill and Johnson (loc. cit.) did not give any reason for not accepting Blake's choice, nor did they acknowledge it. The K specimen is undated. As all sheets at MEL and K bear similar (flowering) material, it is difficult to know whether the Kew specimen is from the 1863 gathering, the 1866 gathering, or perhaps a third gathering. Therefore, it would be unwise to designate the K specimen as an isolectotype.

Eucalyptus brownii Maiden & Cambage, J. & Proc. Roy. Soc. New South Wales 47: 215 (1913).

Type citation: "Type from Reid River near Townsville. (N. Daley, Sept. and Dec., 1912.)". **Lectotype (here designated):** Queensland: Reid River, via Townsville, *N. Daley 8*, December 1912 (NSW303042; isolecto BM (specimen on left-hand side), BRI AQ09642, NSW303043).

Specimens from both of the cited gatherings are present at NSW. One of the two sheets with the collecting number '8' from the December 1912 gathering is here chosen as the lectotype. It has pressed unmounted branchlets bearing adult leaves and mature fruits, and is in accord with the protologue. Fruiting specimens at BM and BRI have the same label details as the lectotype, and can be considered part of the same gathering.

Eucalyptus cambageana Maiden, J. & Proc. Roy. Soc. New South Wales 47: 91 (1913

Lectotype (here designated): Queensland: Mirtna Station, [south of] Charters Towers, *Z. Clark s.n.*, December 1912 (NSW332953; isolecto NSW332954).

The protologue states "Type from Mirtna Station, Charters Towers, Queensland (Miss Zara Clark, January and December 1912)". There are specimens from each of these gatherings at NSW, and they are in accord with the protologue. The December 1912 gathering is more complete. It comprises one sheet of pressed unmounted branchlets bearing adult leaves, mature fruits and immature buds, and a second sheet of pressed unmounted branchlets bearing juvenile leaves. The sheet with fertile material (NSW332953) is here designated as lectotype.

Eucalyptus cloeziana F. Muell., Fragm. 11: 44 (1878).

Type citation: "In montibus orariis ad Rockingham-Bay; Dallachy." **Lectotype** (Chippendale (1988, p. 122): Queensland: Rockingham Bay, *J. Dallachy s.n.*, 22 December 1867 (MEL73642; isolecto K, MEL73641, NSW).

There are two sheets at MEL that have been identified by Mueller as *E. cloeziana* and collected by Dallachy. One sheet (MEL73642) has an original Dallachy label which reads "Coast Range/ 22 December 1867/ This tree has almost lost its foliage; it has large bunches of white fragrant flowers/ The tree is a small one about 30 feet high/ Bark rough and black/ wood brown". The other sheet (MEL73641) lacks a Dallachy label and is undated.

There are also specimens at K and NSW for which the labels state "Rockingham Bay, J. Dallachy". All four specimens bear leafy twigs and clustered inflorescences with open flowers, and it is reasonable to assume that they are part of the same gathering.

Chippendale (1988) cited "T: Rockingham Bay, Qld, 22 Dec. 1867, J. Dallachy s.n.; holo: MEL; iso: K, NSW". In so doing, Chippendale has specified the dated sheet at MEL. Under Article 9.8 of the International Code of Botanical Nomenclature (McNeill *et al.* 2006), his reference to 'holotype' is corrected to 'lectotype'.

Eucalyptus dawsonii R.T.Baker, Proc. Linn. Soc. New South Wales 24: 295 (1899).

Type citation: "Hab. – Ridges on the watershed of the Goulburn River, (R.T.B.) across the main "Divide" at Cassilis and north-west to Pillaga (Prof. Warren)." **Lectotype (here designated):** New South Wales: ranges on the right and left banks of Bylong Creek, Goulburn River, *R.T. Baker s.n.*, November 1892 (NSW19159; isolecto BRI AQ110079, K, NSW326010).

There are no extant collections that have locality data exactly matching the protologue. However there are three sheets at NSW that: (1). have plant material matching the description in the protologue; (2). were collected by R.T. Baker; (3). mention the Goulburn River or 'Bylong', a town in the catchment of the Goulburn River; and (4). were annotated by Baker as *Eucalyptus dawsonii.* These sheets belong to two separate gatherings, with the dates of collection being Nov 1892 and 18 Oct 1898. Maiden (1920) stated "Bylong, 32 miles from Rylstone (R.T. Baker). The type". There are two gatherings that match this statement.

Slee et al. (2006) gave Baker's 1898 specimen at NSW as the lectotype, citing Maiden as the lectotypifying author. The citation by Slee et al. (2006) does not constitute a prior lectotypification, because electronic publication is not effective under Article 29 (McNeill *et al.* 2006). The 1892 gathering is preferred here as it is far superior in quality to the 1898 gathering and because there are specimens from it also at K and BRI. The lectotype comprises pressed unmounted branchlets displaying adult leaves, mature buds, open flowers and fruits.

Eucalyptus intertexta R.T.Baker, Proc. Linn. Soc. New South Wales 25: 308 (1900).

Lectotype (here designated): New South Wales: Nyngan, *W. Baeuerlen s.n.*, November 1899 (NSW330009).

The protologue cites a number of localities for the species, with some collector names included: "Dubbo to the Darling River ('Gum'; W. Baeuerlen); Nymagee, Condobolin ('Coolabah'); Mt. Hope ('Yellow Jacket' and 'Gum'); Cobar ('Coolabah Gum'); Drysdale ('Coolabah'); Bobadah, 30 miles E of Nymagee,.... For these localities I am indebted to Mr R.H. Cambage..."

The date of publication for *E. intertexta* is 25 September 1900 (Chapman 1991). There are just three extant specimens at NSW (where R.T. Baker's herbarium now resides) that were collected prior to September 1900 and correspond to the localities and collectors cited in the protologue. One is a good quality fruiting specimen from Nyngan, collected by Baeuerlen in November 1899; another is a sterile specimen from Drysdale, July 1899, collected by Cambage; and the last is a poor quality fruiting specimen collected by Baeuerlen in March 1900 from Girilambone (Baeuerlen 2475).

Brooker et. al. (1984) cited the type as follows: "Type: Includes Nyngan West, New South Wales, 1900, W. Baeuerlen." This is not a prior lectotypification. The word "includes" shows that these authors were not choosing a single element as a type, but rather were listing one of the specimens that they considered a syntype. There is no specimen with these details at NSW, but there is such a specimen at K. I have chosen as lectotype the Nyngan specimen at NSW collected by Baeuerlen in November 1899. Nyngan lies within the area encompassed by the "Dubbo to the Darling River" statement in the protologue, and the specimen has a label bearing Baker's handwriting. It comprises a single sheet of pressed unmounted branchlets bearing adult leaves and mature fruits.

Eucalyptus malacoxylon Blakely, Key Eucalypts 145 (1934).Basionym: *E. stuartiana* var. *grossa* Maiden, Crit. Revis. Eucalyptus 3: 69 (1917).

Lectotype (here designated): New South Wales: Hanging Rock, Nundle, *J.H. Maiden & J.L. Boorman s.n.,* June 1906 (NSW41833; isolecto A, CANB, K).

The protologue states "... the following notes were made by me in front of it [the tree?] in June, 1906, when it was collected by Mr J.L. Boorman and myself. It occurs, say, 2 miles from Hanging Rock (on the Nundle Road)...".

There are two gatherings that might be considered in the choice of a lectotype. Chippendale (1988) cited them as follows: "Hanging Rock, near Nundle, N.S.W., June 1906, *J.H. Maiden & J.L. Boorman s.n.*; syn: FRI, K, NSW; Hanging Rock, near Nundle, N.S.W., June 1904, *J.L. Boorman s.n.* syn: BM, NSW."

The lectotype designated here has a collection date that closely matches the protologue. It comprises copious pressed unmounted branchlets. If mounted separately the branchlets would probably occupy three or four standard sized herbarium sheets. The branchlets bear juvenile leaves, adult leaves with attached buds (almost mature), adult leaves with attached mature fruits, and there are some separate mature fruits (in a packet).

Eucalyptus melanophloia F.Muell., J. Proc. Linn. Soc., Bot. 3: 93 (1859).

Type citation: "A tractu montano Newcastle Range usque ad sinum Moreton Bay Eucalypto crebra abunde adsociata, solum sterilibus indicans". **Lectotype (here designated):** Queensland: Dawson River, *F. Mueller s.n.,* undated [1856] (K, material on upper half of sheet).

Chippendale (1988) cited two syntypes for *E. melanophloia*, both at K, namely "*Mitchell 485*" and "*Moore s.n.*". This citation was accepted by Hill (2002-04) and Slee et al. (2006). However, I do not accept that these specimens are syntypes. A footnote at the start of Mueller's paper (Mueller 1859) stated "*the accompanying MS. has been compared with the specimens from Dr. Mueller and A. Cunningham in the Hookerian Herbarium, by Mr. Allan Black, Curator of the Herbarium, who has added some habitats and notes*". Throughout Mueller's paper, such additions are discernable by being in a separate paragraph and enclosed in brackets. For *E. melanophloia,* the specimen citations inserted into the text by Mr Black are "(N. Holl. Sub-Trop., Mitchell. Moreton Bay, Moore. Sydney Woods, Paris Exhib. No. 66, in hb. Hook.)". These citations are not part of the protologue of *E. melanophloia* F.Muell., cannot have any bearing on the typification of the name and do not constitute mention of a specimen or gathering, according to Article 37.3, Note 2 (McNeill et al. 2006)..

Mueller did not cite any specimens for *E. melanophloia*, and so the lectotype must be chosen from the original material. The protologue refers to Mueller's travels during the North Australian Expedition (1855-56), led by A.C. Gregory. MEL does not hold any specimens of *E. melanophloia* collected by Mueller, but there are Mueller specimens from four gatherings at K, mounted on two sheets. The localities associated with these gatherings are 'Gilbert River', 'Dawson River', 'Burnett River' and 'Eastern subtropical Australia'. The material collected from Dawson River is of good quality (and is from a region the expedition passed through). It comprises pressed and mounted branchlets; two bearing leaves only and three bearing mature fruits only. This material is in accord with the protologue and is here designated as the lectotype. There is no sheet number currently available for this specimen. The label (written in Mueller's hand) includes the notation "Silver leaved Ironbark tree Colon" [of the colonists].

Eucalyptus morrisii R.T.Baker, Proc. Linn. Soc. New South Wales 25: 312 (1900)

Lectotype (here designated): New South Wales: Girilambone, *W. Baeuerlen s.n.,* December 1899 (NSW310761).

The protologue states that the species occurs "near Girilambone, on stony or rocky hills, thence on hills across country to Cobar; also near Coolabah, where it occurs on more or less level and less stony ground (W. Bauerlen)". Maiden (1917) stated "drawn from the type specimen collected by Mr. W. Baeuerlen at Girilambone". However, there are at least three gatherings made by Baeuerlen from Girilambone before the publication of the name (25th September 1900, Chapman 1991).

NSW310761 is chosen here as lectotype as it is in agreement with the protologue, is a good quality specimen and would have been available to the author. It comprises pressed unmounted branchlets bearing adult leaves, mature buds, open flowers, immature fruits and mature fruits. In addition, there are some loose mature fruits in a packet.

Eucalyptus nova-anglica H.Deane & Maiden, Proc. Linn. Soc. New South Wales 24: 616 (1900); *E. cinerea* var. *nova-anglica* (H.Deane & Maiden) Maiden, Crit. revis. Eucalyptus 3: 9 (1914).

Lectotype (Chippendale 1988, p. 371): New South Wales: Moona Plains, Walcha, *A.R. Crawford 1*, September 1898 (NSW316904).

The protologue states that "It is common over the greater portion of New England. It occurs on the summit of Ben Lomond". This does not constitute mention of a single specimen or gathering (McNeill et al. 2006: Article 37.3, Note 2). Maiden (1914) stated "The type specimen, Moona Plains, Walcha, N.S.W. (A.R. Crawford.)". However, there are Crawford specimens from two gatherings (Feb 1899 and Sep 1898) that match this citation. To overcome the nomenclatural problem of two syntypes, Chippendale (1988) cited the type as "T: Moona Plains, Walcha, N.S.W., Sept. 1898, *A.R. Crawford s.n.*; lecto: NSW, *fide* J.H.Maiden, *Crit. Revis. Eucalyptus* 3: 22 (1914)."

Chippendale (loc. cit.) has effectively lectotypified the name by citing Crawford's September 1898 specimen at NSW, even though this specimen is labelled as Crawford No. 1. The collection made by Crawford in February 1899 is without a collection number.

Eucalyptus raveretiana F.Muell., Fragm. 10: 99 (1877).

Type citation: "In vallibus udis silvaticis et secus ripas umbrosas Australiae orientalis capricornicae; O'Shanesy". **Lectotype (here designated):** Queensland. Rockhampton, *P.A. O'Shanesy* 1390, 17 March 1873 (MEL1517650).

There are specimens of this taxon collected by Bowman, Thozet, O'Shanesy and Fitzalan held at MEL. As Mueller cited "O'Shanesy" as the collector, the lectotype must be chosen from amongst his collections. Chippendale (1988) listed the type as "near Rockhampton, Qld, *P. O'Shanesy s.n.*; holo: MEL; iso: K". However there are three specimens (from three different gatherings) at MEL that were collected by O'Shanesy from the Rockhampton area. Chippendale's statement cannot be readily matched with any one of these gatherings. Each of the three specimens has an original label specifying its place of collection (Rockhampton; Gracemere near Rockhampton; Gracemere), collection date (a different date for each), and collection number.

In the protologue, Mueller described mature buds, stamens, anthers and stigma, and stated "semina matura me nondum visa". The MEL specimen from O'Shanesy's 1873 collection [MEL1517650] bears a single mounted branchlet with adult leaves, buds, open flowers and immature undehisced fruits, and hence is a very good match for the protologue. It is here selected as the lectotype.

Eucalyptus rudderi Maiden, Proc. Linn. Soc. New South Wales 29: 779 (1905).

Lectotype (Chippendale 1988, p. 412): New South Wales: Cundletown, *A. Rudder s.n.*, July 1885 (NSW135705).

The protologue cites the following collections "Cundletown, near Taree (A. Rudder)", "in the counties of Gloucester and Macquarie", and "parish of Bohnock, a few miles from Taree. It appears to favour stony ridges (J. Hardiman)". There are specimens at NSW corresponding to each of the cited localities in the protologue, each from a separate gathering, namely (1). a collection by Rudder from Cundletown; (2). a collection by the District Forester Taree (probably J.J. Hardiman), from county Gloucester, Oct 1904; and (3). a collection cited as by J.J. Hardiman from Parish Bohnock, County Gloucester, 18 August 1904.

Maiden (1911) cited several extra localities, but he did not select any specimen as a type either in the text (pp. 118 and 119) or in the caption for the illustration (p. 132).

Chippendale (1988) cited the type as follows: "Cundletown, near Taree, NSW, Jul 1885, *A. Rudder s.n.*; lecto: NSW, *fide* N. Hall and M.I.H. Brooker, Forest Tree Ser. No. 193 (1977)". However, it is incorrect to infer that Hall and Brooker (1977) chose a lectotype. They wrote that "…Maiden does not specifically state what the type material was. L.A.S. Johnson has chosen as a lectotype a specimen from Cundletown, near Taree." Unfortunately, Johnson never formally chose a lectotype for *E. rudderi* in any of his subsequent publications, but he did annotate the Cundletown sheet with the words "should be taken as the lectotype".

Chippendale's citation of this specimen is here regarded as formally satisfying the requirements of the code (McNeill et al. 2006). The lectotype is a specimen of poor quality comprising two small leafy branchlets and a packet containing some flowers and very immature fruits. Nevertheless it is identifiable as the taxon now known as *E. rudderi.*

Eucalyptus thozetiana (Maiden) R.T.Baker, Proc. Linn. Soc. New South Wales 31: 305 (1906); *E. calycogona* var. *thozetiana* Maiden, Crit. Revis. Eucalyptus 1: 87 (1903).

Type citation: "I have examined specimens from (a) Expedition Range, Queensland, (M. Thozet, in herb. Melb.); (b) 'Eucalyptus from the Mackenzie River, Queensland. It sheds all the bark except that on the butt of the trunk' (W. Woolls, who labelled it E. tesselaris); (c) and (d) Warrego and Flinders River, Queensland (F.M. Bailey). The fruits are small, narrow, and sub-cylindrical, but perhaps not perfectly ripe." **Lectotype** (Brooker et al. 1984, p. 506): "Expedition Range (southeast of Emerald), Queensland, A. Thozet"; (**lecto** MEL 231745 (**here designated**); isolecto NSW333172).

E. gracilis var. *thozetii* F.M.Bailey, Queensland Fl. 2: 615 (1900), *nomen nudum.*

Mueller (1879) made an obscure reference to the species to which the name *E. thozetiana* is now applied. In his treatment of *Eucalyptus gracilis,* he wrote "either as a variety, or perhaps even as a species can be distinguished from *E. gracilis,* an *Eucalyptus* gathered by the lamented late Monsieur A. Thozet in his last botanical journey to Expedition Range." Although Mueller did annotate some specimens at MEL with the name "*E. thozetiana*", he never effectively published the name.

Maiden (1903) was the first to validly publish the epithet "*thozetiana*" in the combination *E. calycogona* var. *thozetiana.* He cited four gatherings:

Baker (1906) provided a detailed description and discussion of the species for which he adopted the name *E. thozetiana.* He attributed the name to Mueller, based on the statement quoted above. This has given rise to the commonly quoted authorship of "F.Muell. ex R.T.Baker". Baker acknowledged the "var. *thozetiana*" erected by Maiden (1903), and merely raised it to species rank, so that the authorship of *E. thozetiana* should be "(F.Muell. ex Maiden) R.T.Baker" or "(Maiden) R.T.Baker".

Brooker et al. (1984) stated "Type: Expedition Range (southeast of Emerald), Queensland, A. Thozet." While there is only one gathering that fits this statement, specimens from it exist at both NSW and MEL. In accordance with Article 9.15 (McNeill et al. 2006), the initial lectotypification of Brooker et al. (1984) is here narrowed to the MEL specimen. The MEL specimen has been chosen in preference to the NSW specimen because Maiden stated in the protologue that he had examined the Thozet specimen "in Herb. Melb.".

Eucalyptus viridis R.T.Baker, Proc. Linn. Soc. New South Wales 25: 316 (1900).

Type citation: "on the hills near Girilambone, N.S.W., thence across country to Cobar; also seven miles out from Coolabah on the Wilga Downs road (W. Baeuerlen) **Lectotype (here designated):** New South Wales: Girilambone, *W. Baeuerlen 2535,* March 1900 (NSW333684; isolecto NSW333679, NSW333681, NSW333682 & NSW333683).

Maiden (1910), in the caption for an illustration of *E. acacioides,* stated "Girilambone, N.S.W. (W. Baeuerlen.) Type of *E. viridis,* R. T. Baker". There are at least three gatherings that match Maiden's statement. Baeuerlen's March 1900 gathering comprises five sheets at NSW. These specimens have original labels in the handwriting of W. Baeuerlen, and would have been available to the author before publication, as the name was published on the 25th September 1900 (Chapman 1991). The unmounted material on these sheets is of good quality with branchlets bearing leaves, mature buds, flowers and fruits. The buds and fruits are a good match for those shown in the illustration in the protologue, but no specimens have been found with misshapen leaves as portrayed in that illustration. NSW333684 has been chosen as the lectotype, with the remaining sheets being regarded as isolectotypes.

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A new *Caulokaempferia* (Zingiberaceae) from Thailand

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Abstract

A new species of ***Caulokaempferia*** (Zingiberaceae) from northern Thailand, ***C. chayaniana,*** is described and illustrated. The affinities of this new species with the morphologically similar taxon, *C. larsenii* Suksathan & Triboun, are also discussed.

Introduction

The family Zingiberaceae may be considered the most important medicinal plant group of the Monocotyledonae in the Thai culture. Members of the family are widely used in food and medicine and some are also integral to the spiritual beliefs of Thai rural society. Our study of the genus *Caulokaempferia* in Thailand was inspired by an unknown taxon widely used by the "forest monks" in northeast Thailand as a major ingredient in the treatment of prostatic hyperplasia (enlarged prostate gland). As a result of intensive studies of the genus, this medicinal plant was recently recognised as *C. phutokensis* Picheans. (Picheansoonthon & Koonterm 2008, Chaiyoot et al. 2008). Taxonomic study of the whole genus is ongoing with the aim of providing fundamental knowledge of this plant group for future drug research and development.

The genus *Caulokaempferia* K. Larsen comprises about 25 species, distributed from the Himalayas through south China, Indochina and Thailand, with its centre of diversity in Thailand (Chaiyoot 2007). At least 15 taxa have been reported recently from Thailand (Chaiyoot 2007) and the non-yellow flowered taxa transferred to a new genus, *Jirawongsea* Picheans. (Picheansoonthon et al. 2008).

An unknown population of this genus was first discovered during intensive fieldwork in October 2007 but the flowers were all past bloom. Follow-up excursions to the same location were carried out in May and July 2008, and June 2009 and further expanded to search for other populations. This unknown taxon is recognised as *C. chayaniana* in this paper. A full description, illustrations, and discussion of the morphological affinities of this species with *C. larsenii* Suksathan & Triboun are included.

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Caulokaempferia chayaniana Tiyaw., ***sp. nov.***

Diagnosis: Caulokaempferiae larsenii *similis sed foliis amplexicaulibus, ligulis brevioribus (1.5–3 mm contra 6–9 mm longis), corollae lobo dorsali ovato, lobis lateralibus apicibus rotundatis, staminodiis apicibus emarginatis, filamentis longioribus (1–2 mm contra 0.5 mm longis) differt.*

Holotype: Thailand: Mae Hong Son Province: Pai District: Doi Jik Jong, *C. Picheansoonthon 1017*, 10 July 2008 (BKF). Isotypes: BK, SING.

Perennial herb with short rhizome; roots fibrous, some forming a longish storage tuber. Pseudostem slender, erect, 12.5–37.4 cm long. Leaves 5–8, the lowermost 2–4 strongly reduced to bladeless leaf sheaths; lamina sessile, ovate to ovate-lanceolate, both sides glabrous, the largest ones 6.0–13.5 × 1.7–5.7 cm, with cordate, amplexicaul bases, apex acute to acuminate, margin slightly undulate; ligule membranous, 1.5–3.0 mm long, apex rounded. Inflorescence terminal, 3.5–8.5 cm long; peduncle glabrous, 2.2–5.5 cm long. Bracts 3–8, distichous, ovate to lanceolate, glabrous, 3.1–4.0 × 0.5–1.7 cm, acute, margin membranous, each enclosing a 1–3 flowered cincinnus; bracteoles elliptic, c. 1 × 0.5 cm, margin membranous. Flowers entirely yellow. Calyx tubular, glabrous, hidden in the bract, 1.2–1.5 cm long, split c. 2 mm down on one side, apex bi- or trilobed, or 3 or 4-dentate. Corolla tube 2.5–3.7 cm long, c. 2 mm wide, 3-lobed; dorsal lobe ovate, 1–1.3 × 0.6–0.7 cm, hooded with apex forming a c. 0.5 mm thorn-like point, lateral lobes ovate-oblong, 1.4–1.7 × 0.5–0.6 cm, apex rounded, hooded. Lateral staminodes obovate, 1.4–1.8 × 1–1.3 cm, apex emarginate. Labellum suborbicular, 2.4–3.2 × 1.2–2.2 cm, flat with saccate base, margin wavy. Functional stamen with very short filament, 1–2 mm long; anther oblong, c. 5 × 3 mm; anther crest broadly ovate, 3–4 × 5–6 mm, slightly reflex. Ovary oblong, 3–5 mm long, glabrous; stylodial glands 2, spherical c. 0.5 mm long; style linear (inserted between anther sacs); stigma cup-shape, 2–3 mm diam, margin ciliate. Fruit a unilocular fleshy capsule, ovoid-oblong, glabrous, 1.5–2 × 0.5–0.6 cm, greenish. Seed numerous, light brown, ellipsoid, c. 2 mm long. Flowering June–July; fruiting July–September. (Figs 1 & 2)

Distribution: this species has so far been found only at the type location. It is distributed in a very limited area.

Ecology: this new species grows in moist granite clefts and in rock cleavages under evergreen lower montane scrub at an altitude of 900 m.

Use: the whole plants, with other herbs, are used by the Shan ethnic group for gastric disorders.

Etymology: the specific epithet of this new taxon is named to honor Dr.Chayan Picheansoonthon, fellow of the Royal Institute of Thailand, in recognition of his contribution to our knowledge of the family Zingiberaceae in Thailand and Laos, in particular the genus *Caulokaempferia*. He has studied this genus and published several new species, the most recent of which include *C. satunensis* Picheans. (Picheansoonthon et al. 2007), *C. phuwoaensis* Picheans. & Koonterm, *C. phulangkaensis* Picheans., *C. phutokensis* Picheans. (Picheansoonthon & Koonterm 2008), and *C. bolavenensis* Picheans. & Koonterm (Picheansoonthon et al. 2008).

Note: this new species is similar to *C. larsenii* Suksatan & Triboun (Figs. 3a & b) in several key characters, i.e. the open leaf sheaths, the presence of a ligule, the shape of the inflorescence, and the number of flower(s) per bract. However *C. chayaniana* differs from the latter taxon by its amplexicaul leaves; shorter ligules (1.5–3 mm versus 6–9 mm) with rounded apices; lanceolate to ovate bracts with pointed apices; calyx tubes with bi- or trilobed to 3- or 4-dentate apices; ovate dorsal corolla lobes; and ovate to oblong lateral corolla lobes with emarginated apices.

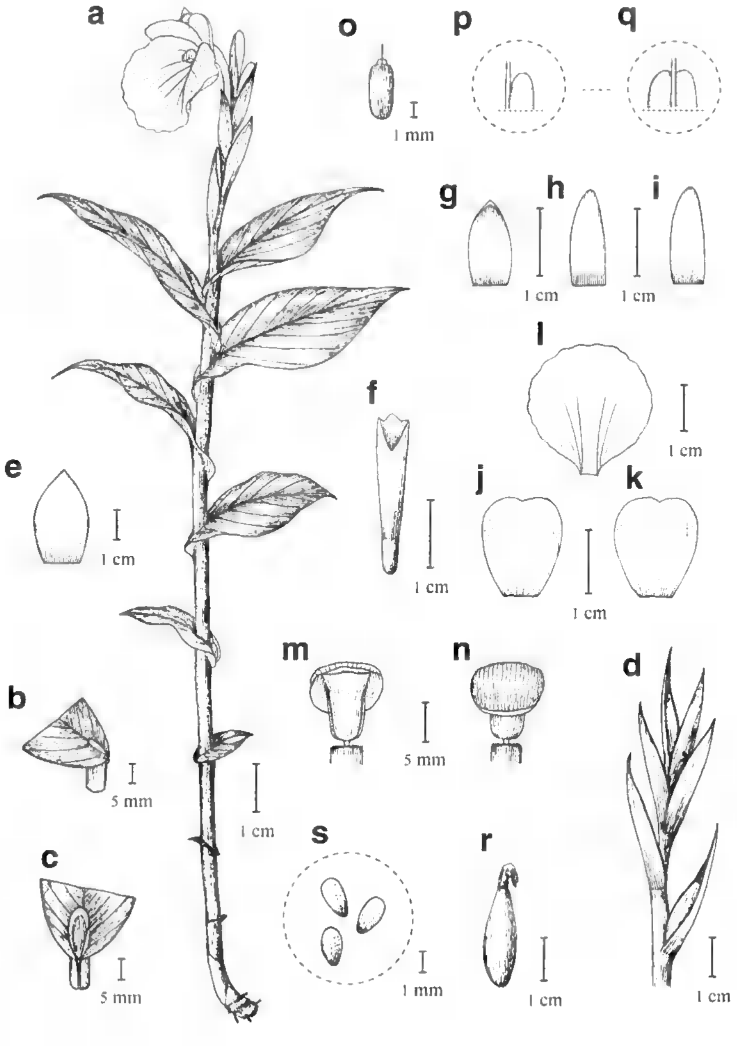

Fig. 1. *Caulokaempferia chayaniana* Tiyaw. **a,** habit; **b & c,** leaf base, showing ligule (b, side view; c, front view); **d,** infructescence; **e,** bract; **f,** ovary and calyx tube; **g,** dorsal corolla lobe; **h & i,** lateral corolla lobes; **j & k,** lateral staminodes; **l,** labellum; **m,** stigma, anther and anther crest (ventral view); **n,** anther and anther crest (dorsal view); **o,** ovary, part of style and stylodial glands; **p & q,** enlargement of stylodial glands (p, side view; q, front view); **r,** fruit; **s,** seeds (all from type locality, drawn by Chalermchoke Boonchit).

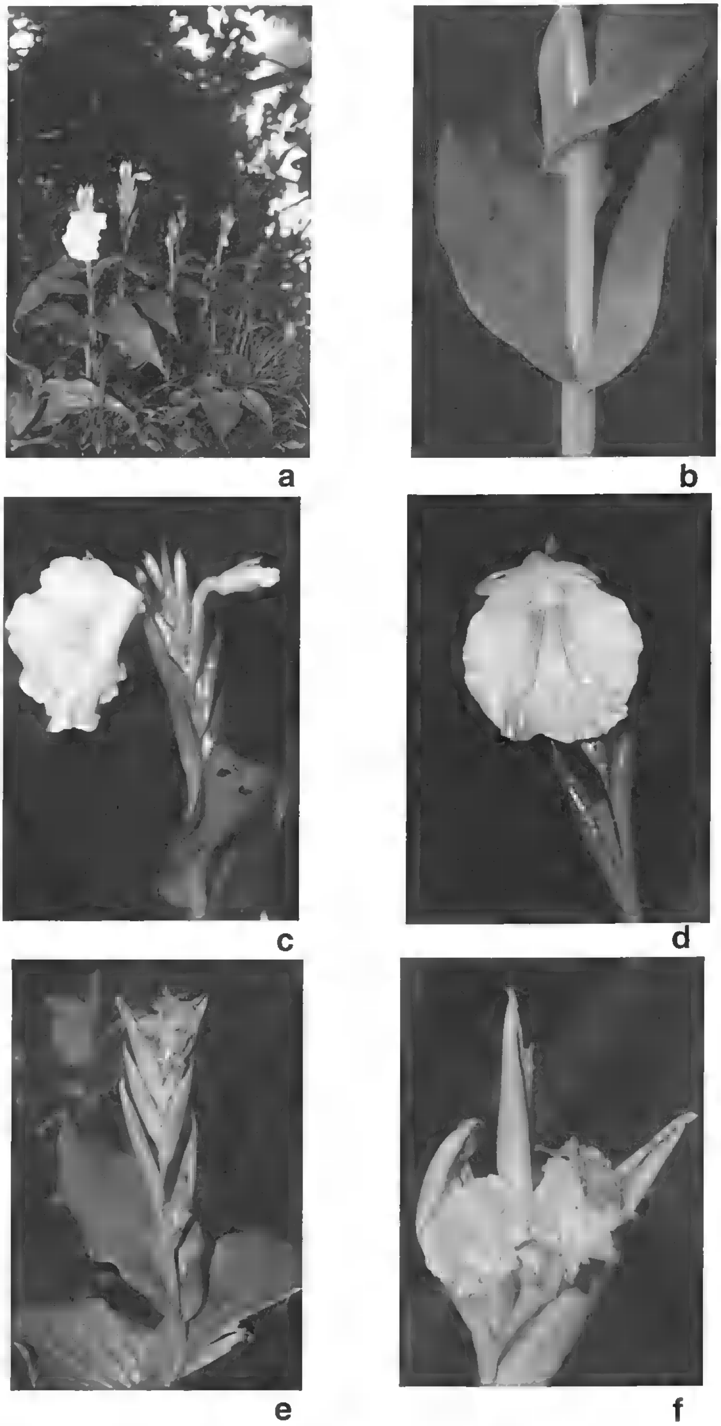

Fig. 2. *Caulokaempferia chayaniana* Tiyaw. **a,** habit; **b,** part of stem showing amplexicaul leaf bases; **c,** inflorescence showing distichous bracts and flowers; **d,** flower (front view); **e,** infructescence; **f,** infructescence with open capsules showing seeds inside (all from type locality; a, c & d photographed by Pornpimon Wongsuwan; b, e & f photographed by Chayan Picheansoonthon).

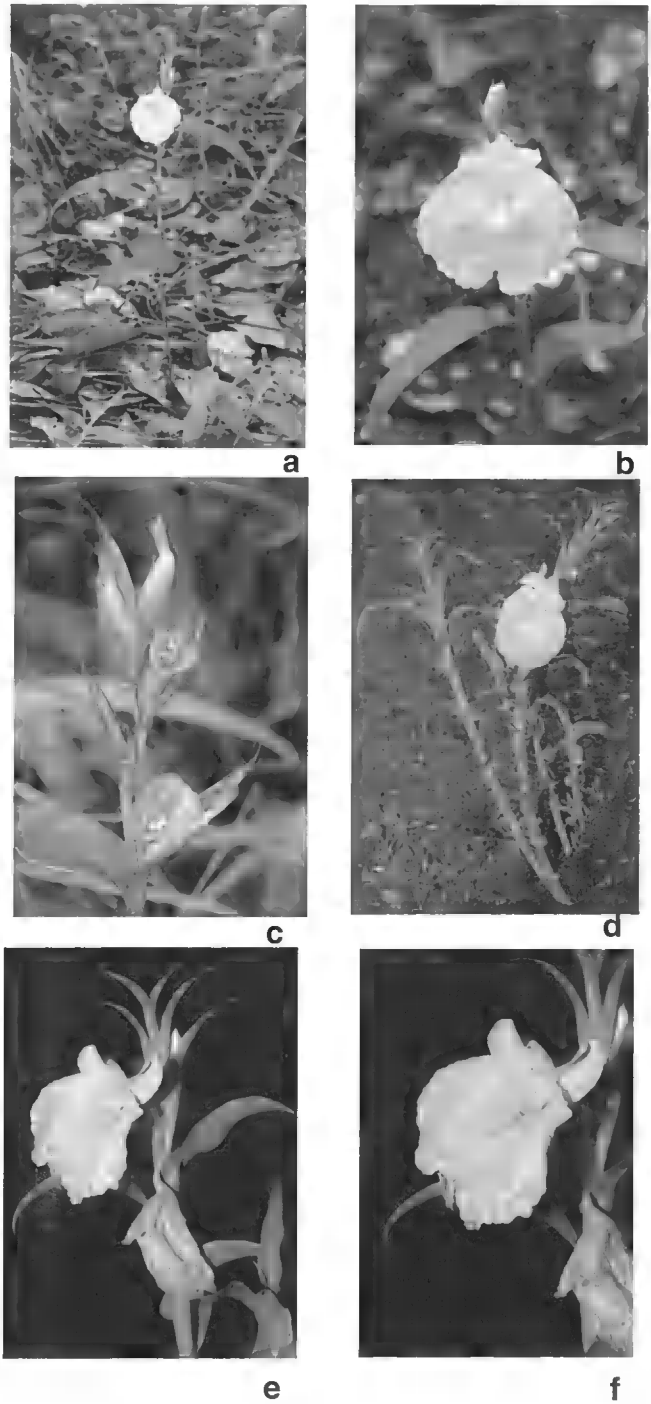

Fig. 3. a–c, *Caulokaempferia larsenii* Suksthan & Triboun. **d–f,** *Caulokaempferia amplexicalis* Suksthan. **a,** habit; **b,** an inflorescence showing a flower; **c,** an infructescence; **d,** habit; **e,** an inflorescence showing the distichous bracts and a flower; **f,** a flower (all plants from type localities, photographed by Chayan Picheansoonthon).

This new taxon also resembles *C. amplexicaulis* Suksathan (Figs. 3e & f) in its inflorescence structure and the amplexicaul leaves. The latter taxon is unique in its closed leaf-sheath without a ligule, Also, the inflorescence of *C. amplexicaulis* is characteristic in its leaf-like bracts with recurved apices subtending strictly one flower.

Biogeographically, it is worth noting that the type locations of *C. chayaniana* and *C. amplexicaulis* are on the clefts of the two high mountain peaks facing each other, approximately 100 kilometers apart, in the Pai Valley (Thailand, Mae Hong Son Province) adjacent to the border with Myanmar.

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Aleuritopteris punethae (Pteridaceae) a new species of silver fern from Indian Himalaya

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Abstract

A new species of ***Aleuritopteris*, *A. punethae*,** is here described from central Himalaya, India. This species has triangular-deltoid lamina similar to those of *A. argentea* and *A. tamburii* that also occur in the Himalayan region.

Introduction

Silver or Lip Ferns are widespread in the eastern and western hemispheres and exhibit a wide range of variability in frond morphology. This variability has resulted in as many as nine generic names being applied to them (Copeland 1947, Pichi-Sermolli 1978), in addition to *Cheilanthes* Sw. However Ching (1941), following Fée (1852), advocated that the Asian species, which differ from the American ones in having golden or white farina and a differently shaped lamina should be transferred to *Aleuritopteris* Fée. Tagawa (1959), Nayar (1962), Iwastuski (1988) and Kramer and Green (1990) retained the Asian species in *Cheilanthes,* whereas other authors, including Panigrahi (1960), Saiki (1984a, 1984b, 1984c), Shing & Wu (1990), Wu (1981), Singh and Panigrahi (2005), Smith et.al. (2006) and Fraser-Jenkins (2008) accept *Aleuritopteris* as distinct from *Cheilanthes.* The latter position is supported by the recent molecular studies of Gastony and Rolo (1995,1998) and Schuettpelz et al. (2007).

During the collection of lower vascular plants from some remote areas of the Pithoragarh district, eastern Kumaon (Indian Himalaya), the authors came across a small silver fern (Fig. 1). On the basis of its small fronds with a farinose triangular fertile lamina, it was identified as *A. argentea* (Gmel.) Kunze (Punetha et al. 2008). Some experts, including Fraser-Jenkins, present at the International Symposium on Perspectives in Pteridophytes held at National Botanical Research Institute, Lucknow (India) in November, 2008 did not accept this assessment. Fraser-Jenkins also encouraged the first author (BSK) to examine the specimens of *Aleuritopteris argentea* collected from Sikkim by Riboo Rhomoo (Collector of Sir J. D. Hooker) and housed in the herbarium of the Lloyd Botanical Garden, Darjeeling, India (not in Index Herbariorum). On comparison with these specimens and other deltate farinose species in *Aleuritopteris* sect. *Argentae* (Ching 1941) from Indian Himalaya, i.e. *A. tamburii* (Hook.) Ching and *A. albomarginata* (Clarke) Ching, it was found that the present taxon is distinctively different from them.

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For further confirmation, literature on *Cheilanthes* Sw. and *Aleuritopteris* Fée (such as Beddome 1883; Clarke 1880; Hope 1899, 1900; Ching 1935, 1941; Nayar 1962; Wu 1981, 1990; Ching & Wu 1983; Saiki 1984a; Shing & Wu 1990; Fraser Jenkins 1997, 2008; Zhang et. al. 2007) from Himalaya and Asia was also consulted but it did not match any species described earlier. A photograph of the plant was also sent to Prof. S. K. Wu (KUN) and Prof. X. C. Zhang (Institute of Botany CAS) for confirmation and comparison with species from China (where most diversity of this genus exists). The critical observations and comments from these Chinese experts, who have extensive knowledge of *Aleuritopteris*, has encouraged us to describe this plant as a new species.

New Species

Aleuritopteris punethae Kholia, Bhakuni et R.Punetha ***sp. nov.***

Cheilanthes argentea sensu Punetha et. al., J. Indian Bot. Soc. 87(3&4): 289–290, 2008, non (Gmel.) Kunze.

Rhizoma breve erectum apice sparse squamatum; squamae 2 mm longae nigrae lanceolatae, marginibus integris, apice acuto. Frondes dimorphae; stipites caespitosi castanei foliorum sterilium 6 cm longi, fertilium 9 cm longi, basi sparse squamosi supra glabri; squamae ut in rhizomate; laminae subcoriaceae, peltatae, 4.3–4.5 cm longae pinnatifidae, infra dense vivide albo-farinosae; laminae steriles latiores quam fertiles, pentagonae; laminae fertiles triangulares attenuatae; pinnae laterales 4 vel 5 paribus rhachide adnatae; pinnae basales maiores in laminis sterilibus 2.5 cm longae, in fertilibus 3 cm, parte basiscopica profunde lobata; pinnae superae gradatim reductae ad rhachim non profunde incisae; lobi lati, marginibus integris apice obtuso; rachis alata; nervi non obscuri; sori marginales secus margines continui; indusia solida; sporae globosae atrofuscae, perinio verrucoso, 40 × 40 μm.

Type: India, Himalaya, Pithoragarh, Munsyari, New Lilam in Gori river valley, altitude c. 1800m, September 2006, *Kamlesh Bhakuni 307*, 24 Sep 2005 (Holotype: BSHC 41337, Isotype: Herb. Bot. Pithoragarh) Fig. 1.

Rhizome short, erect, sparsely scaly at apex; scales 2 mm long, black, lanceolate, margins entire, apex acute; fronds dimorphic; stipe tufted, chestnut brown, 6 cm long (in vegetative) 9 cm long (in fertile), sparsely scaly at base glabrous above; scales as on rhizome; lamina subcoriaceous, peltate, 4.3–4.5 cm long, 1-pinnatifid; undersurface densely farinose, farina bright white; barren lamina wider than the fertile, pentagonal, fertile lamina triangular, narrowed; lateral pinnae 4 or 5 pairs, adnate to rachis, basal largest, 2.5 cm long in vegetative lamina, 3.0 cm in fertile, and deeply lobed on basiscopic side, basal basiscopic pinnules of basal pair of pinnae also adnate laterally at least at base, upper pinnae gradually reduced, not deeply cut to the rachis; lobes broad, margins entire, apex obtuse; rachis winged; veins not obscure, once or twice forked; sori marginal, continuous all along the margins; indusium firm, spores globose, dark brown, perine verrucose, 40 × 40 μm.

Habit: lithophyte on rock crevices at semi exposed locality.

Etymology: the species epithet of the plant is named after Dr. N. Punetha, Professor of Botany, Post Graduate College, Pithoragarh, Uttarakhand, India for his outstanding contribution on the morphology of Pteridophytes and pioneering work on the Pteridophyte Taxonomy in Kumaon Himalaya.

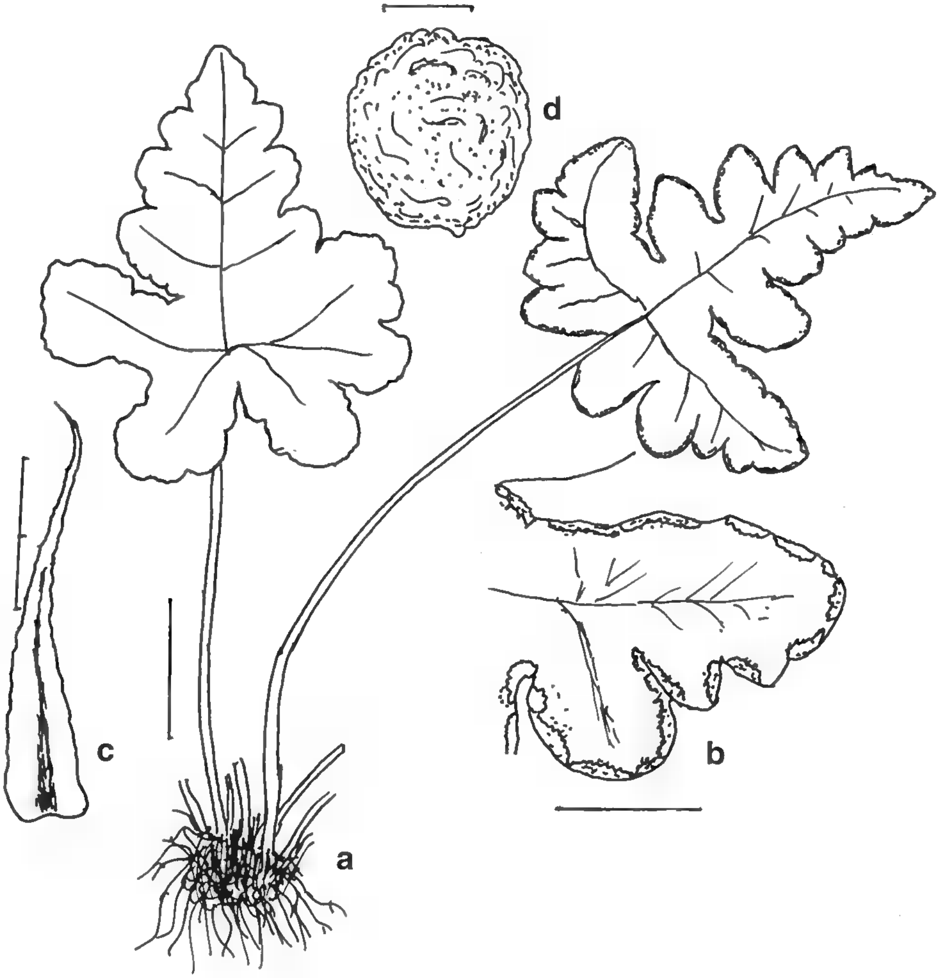

Fig. 1. *Aleuritopteris punethae* **a,** habit; **b,** part of lamina showing indusia; **c,** rhizome scale; **d,** spore.

Distribution: the species is at present known only from the type locality.

The other two species occurring in Indian Himalaya with triangular-deltoid lamina are *A. argentea* and *A. tamburii* but in the former the lamina is distinctly pinnate with 6 or more pairs of lateral pinnae which are distant on the rachis, either pinnatifid or lobed, and only the upper pinnae are adnate to rachis. In *A. tamburii* the second pair of pinnae is always smaller than the basal and third pairs, often lobed to give a butterfly like appearance, but in *A. punethae* the lateral pairs of pinnae are fewer in number, gradually reduced and adnate to rachis. They are also jointed to each other and form a regular wing throughout the length of the lamina, so that the rachis is not free. The stipe:lamina ratio is nearly equal in these two species whereas in *A. punethae*, the stipe is longer than the lamina in fertile fronds. The new species also differs from another Indo Himalayan member of section Argentae (Ching 1941), *A. albomarginata*, by its smaller size, much more deltate and less dissected lamina, as well as the absence of scales on the costa and costules.

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Vegetative anatomy of *Finschia* Warb. and its place in Hakeinae[‡] (Proteaceae)

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Abstract

The leaf anatomy of three species of *Finschia* included in the subtribe Hakeinae (Proteaceae) is described. The stem-node-leaf continuum is described in *F. chloroxantha* Diels and *F. rufa* Warb.. Within the genus, features of the leaf epidermis make it possible to distinguish species and are consistent with synonymy between *F. rufa* and *F. carrii* (Sleumer) C.T.White. Anatomical characteristics are compared with those of *Grevillea* and *Hakea* and similarities that might support relationships are discussed.

Introduction

Finschia comprises three Papuasian species and is currently recognised as a member of tribe Embothrieae, subtribe Hakeinae (Proteaceae) (Weston & Barker 2006). All *Finschia* species are trees with buttressed trunks, often raised on stilt roots. *Finschia ferruginiflora* is restricted to the Eastern Highlands and Western Highlands of Papua New Guinea; *Finschia rufa* is known from Madang, Morobe, Eastern Highlands and Western Highlands, Central and Milne Bay districts of Papua New Guinea (Foreman 1995); and *Finschia chloroxantha* is more widely distributed in Papua New Guinea (Conn & Damas 2006+) and extending to the Aru Islands, Solomon Islands, New Hebrides and Palau Islands.

Finschia Warb. was circumscribed by Warburg (1891) but became the object of controversy in the first half of the twentieth century. Lauterbach (1913) distinguished *Finschia* from *Grevillea* R.Br. but Diels (1916) rejected the separation of the two genera on the grounds that, although characters of the fruits were described, fruits of neither *F. rufa* nor *F. chloroxantha* had been seen. Sleumer (1939) included *Finschia* in *Grevillea* R.Br. and gave a key to the New Guinea species. White (1949) revised the genus, amended Warburg's description, described a new species and proposed a new combination. He delimited four species, *F. rufa* Warb., *F. carrii* (Sleumer) C.T.White, *F. ferruginiflora* C.T. White and *F. chloroxantha* Diels but Foreman (1995) subsequently decided that *F. rufa* and *F. carrii* were synonymous.

[‡] In the original title this was cited as "Grevilleeae" but the editorial committee chose to use the more recent classification of Weston and Barker (2006) on the recommendation of the referees.
[†] died 15th April, 2005

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The wood anatomy of *Finschia* has been reported on in general works (Furuno 1977, Ilic 1991, Metcalfe & Chalk 1950, Streimann 1969). Chattaway (1948) included the genus in her study of the wood anatomy of the Proteaceae but no account of the leaf and nodal anatomy of *Finschia* has been published.

A list of the specimens studied, including details of collectors and locations, is given in appendix A.

Methods

Methods were those used to study the anatomy of leaves and nodes of *Hakea* (Catling & Gates 1995a, b). Material of herbarium specimens was reconstituted by boiling in water for 10 minutes, and mounted in a split cork and sections 20µm thick cut using a Reichert OME microtome. Sections were cleared in sodium hypochlorite solution, stained with safranin and alcian blue, dehydrated in a graded alcohol series, cleared in Histoclear and mounted in DePex or Canada Balsam.

Observations

Finschia chloroxantha

Stem

Stems included in the stem-node-leaf continuum measured 3-4 mm in diameter and were surrounded by 5-6 layers of superficial cork. The epidermis was disrupted. The cortex was 5–11 cells wide, complementing the size of fibre caps associated with vascular bundles; mostly unlignified but contained some lignified cells and groups of large sclereids; some cells contained tannin. There was a more or less continuous ring of pericyclic sclerenchyma. As well as fibres, this included sclereids which often, though not necessarily, coincided with medullary rays. Vascular tissues were eustelic to weakly siphonostelic and a continuous cambial zone was recognisable. There were interxylary fibres. Pith was lignified and included many large groups of sclereids, especially near developing leaf traces.

Node

Leaf traces spanned only a short distance between the stele and the petiole. They did not extend into adjacent nodes. Traces were recognised by increased numbers of vessels in stelar bundles. At higher levels, modified xylem consisted of simple vascular elements and unlignified parenchyma. Below nodes, near leaf traces, stelar bundles divided and merged. Outside the leaf traces, the cortex was wider and enclosed numerous sclereids.

In the specimen collected by *Powell*, ten nodes were examined. Lateral traces and eight median traces were continuous with single stelar bundles. In two nodes, in the median position, two stelar bundles were modified. In three nodes examined in *BSIP5577*, there was a single stelar bundle associated with each lateral trace. In one node, in the median position, there was a complex of three bundles. In one of the nodes in *NGF9123*, there was a single modified stelar bundle in the position of each lateral leaf trace, in the other, there were four on one side and three on the other. In the median position, three or six bundles were modified.

Leaf base

Leaves were petiolate.

The base of the petiole was first recognised by an absence of cork and by an abscission layer within the stem (Fig. 1). In fibre caps associated with leaf traces, cells were dispersed and mixed with parenchyma (Fig. 1). No sclerenchyma crossed the abscission layer. Towards the lamina there were increased amounts of lignified parenchyma and fibres within the petiole and, where the median leaf trace crossed the abscission layer, there was a weakly-developed fibre cap ahead of it (Fig. 1). Above this, the trace divided and there was a fibre cap associated with each brand. Lateral leaf traces were within the cortex.

At this level, within the stele, one or two small bundles on either side of the median leaf gap had modified xylem. At higher levels, they passed into the petiole where they were inversely orientated and completed a ring of vascular bundles.

Lateral leaf traces entered the petiole. Near the abscission layer, they branched and some tissues formed small vascular bundles on the margins of the leaf base, outside the main circle. There were numerous sclereids in the petiole and in the cortex of the stem, many in a broken line close to the adaxial side of the abscission layer (Fig. 2).

Where the petiole became separate from the stem, it contained a ring of small bundles. Bundles in the abaxial arc had well developed abaxial fibre caps and smaller groups of adaxial fibres. Small groups of abaxial and adaxial fibres were associated with each inverted bundle. Towards each margin there were two or three closely associated small bundles (Fig. 3).

Petiole

Towards the lamina, lateral bundles and bundles towards the abaxial surface were in a broad arc. Abaxial fibre caps were partially merged; adaxial fibres were in discreet groups.

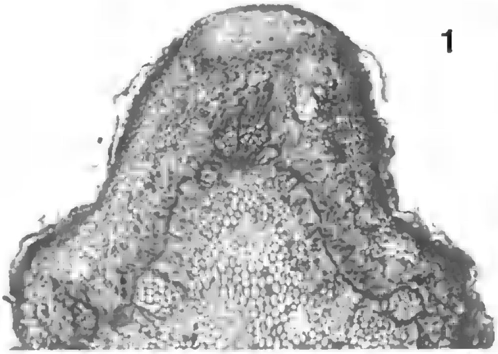
Towards the adaxial side, in three of the five specimens examined, there were well defined inverted bundles (Fig. 4). In material collected by *Powell* and in *NGF 9123*, groups of vascular tissues were less precisely orientated. In material collected by *Powell*, these vascular groups were not seen in the distal region of the petiole; occasional vascular elements occurred among adaxial fibres.

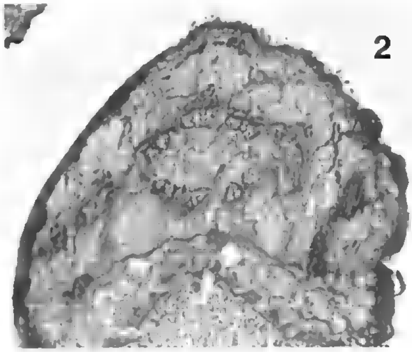
At lower levels towards the base of the petiole, there were adaxial and abaxial fibres associated with each inverted group of vascular tissues. At higher levels, there was a continuous band of adaxial fibres.

Transition from petiole to leaf

Towards the distal end of the petiole, there were 2 adaxial marginal extensions. Two lateral bundles were separated from the main arc by unlignified parenchyma (Fig. 5).

In *BSIP5577* and *Akorra 238*, inverted bundles occurred in lower levels of the leaf although they were not seen at the centre.





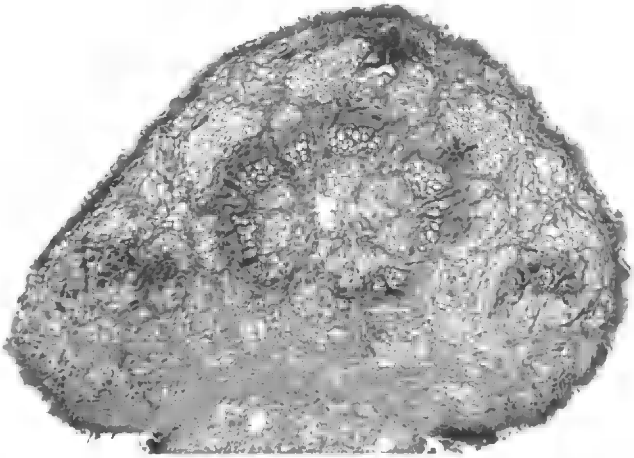

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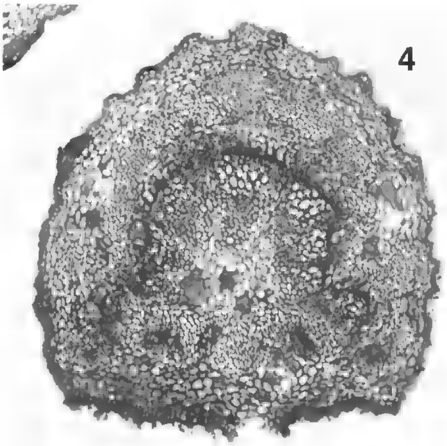
Fig 1. *Finschia chloroxantha* (*NGF9123*); transverse section of node showing an abscission layer and the absence of cork . No sclerenchyma crosses the abscission layer. There is a weakly-developed fibre cap below where the median leaf trace crosses the abscission layer. (c. × 30).

Fig 2. *Finschia chloroxantha* (*NGF9123*); transverse section of leaf base showing the lateral leaf traces entering the petiole. Near the abscission layer, they form small vascular bundles on the margins of the leaf base, outside the main circle. There are numerous sclereids in the petiole and in the cortex of the stem, many in a broken line close to the adaxial side of the abscission layer. (c. × 25).

Fig 3. *Finschia chloroxantha* (*NGF9123*); transverse section of leaf base where the petiole separates from the stem; it contains a ring of small bundles. Bundles in the abaxial arc have well-developed abaxial fibre caps and smaller groups of adaxial fibres. Small groups of abaxial and adaxial fibres are associated with each inverted bundle. Towards each margin there are two or three closely associated small bundles. (c. × 30).



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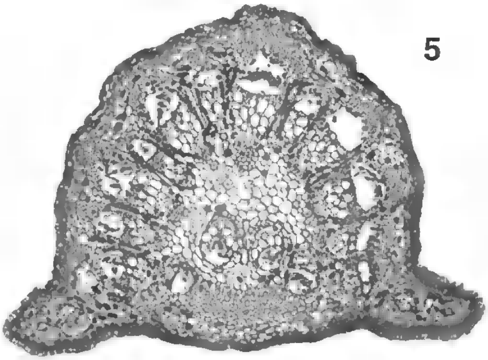

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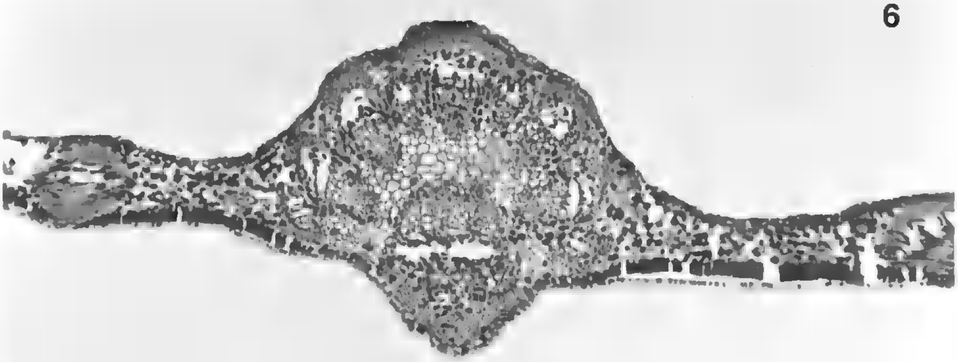

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Fig 4. *Finschia chloroxantha* (*NGF9123*); transverse section of petiole; lateral bundles and bundles towards the abaxial surface are in a broad arc. Abaxial fibre caps are partially merged; adaxial fibres are in discreet groups. (c. × 30).

Fig 5. *Finschia chloroxantha* (*NGF10358*); transverse section of leaf base. Towards the distal end of the petiole, there are 2 adaxial marginal extensions. Two lateral bundles are separated from the main arc by unlignified parenchyma. (c. × 30).

Fig 6. *Finschia chloroxantha* (*NGF10358*); transverse section of midrib. All palisade cells contain tannin, some cell walls are lignified. Abaxial to the palisade, are 10-12 rows of mesophyll cells which are more spongy nearer the surface. One subepidermal row contains tannin. Main bundles are predominantly collateral with abaxial phloem. At the midrib, there is an abaxial arc of bundles of various sizes, each with an abaxial fibre cap. (c. × 30).

Leaf

In outline, in transverse section, abaxial and adaxial surfaces were parallel. Margins were hardly recurved. The leaf was thicker over main veins. At the midrib, the abaxial side of the leaf was convex and there was a pointed adaxial ridge.

Leaves were dorsiventral. The abaxial epidermis consisted of a single row of irregularly rectangular cells. In surface view, anticlinal walls were sinuous. The stomata were brachyparacytic, only occurred on the abaxial surface and were not sunken below the general level of the epidermis. In the adaxial epidermis, cells were more regularly rectangular and anticlinal walls straighter. Outer epidermal walls were cutinised on the adaxial surface and at margins and more weakly cutinised on the abaxial surface. T-shaped hairs, similar to those in many members of the Hakeinae (Heide-Jorgensen, 1978) occurred on both surfaces. The bases of these were not sunken and they were mostly deciduous. There were small, occasional, collapsed glandular hairs. Some epidermal and mesophyll cells contained crystals.

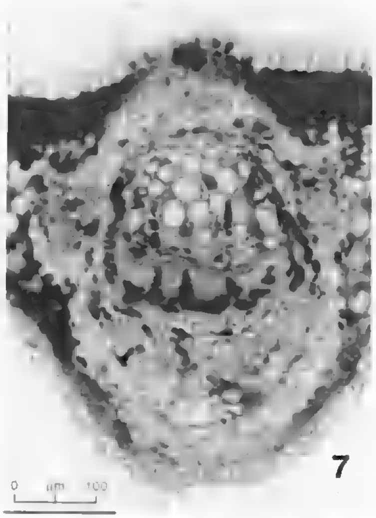
In material collected by *Powell* and in *NGF10358*, palisade consisted of a single row of upright cells interrupted at main veins. In *BSIP5577* and *Akorra 238*, cells were taller and narrower. In *NGF9123*, there was a second, irregular row of square cells. All palisade cells contained tannin. Some cell walls were lignified. There were pronounced pits in anticlinal walls. Abaxial to the palisade, were some 10–12 rows of mesophyll cells which were more spongy nearer the surface. One subepidermal row contained tannin.

Main bundles were predominantly collateral with abaxial phloem. At the midrib, there was an abaxial arc of bundles of various sizes, each with an abaxial fibre cap (Fig. 6). In all the specimens, there was some merging and dividing of fibres and vascular tissues. The number of bundles in the arc varied from 9–16. In three specimens there were 5 main bundles. In *NGF10358* there were 9 bundles of more or less equal size and, in *NGF9123* and *BSIP183*, there was considerable fusion of tissues. Adaxial fibres were associated with vascular groups. Bundles were separated by lignified parenchyma cells, some of which contained tannin. There were some 5-7 rows of abaxial unlignified cortical parenchyma; a morphologically distinct subepidermal row contained tannin. In *NGF10358* and *BSIP183*, there were fewer rows of abaxial cortical parenchyma and, in *NGF 9123*, the subepidermal row was less distinct.

On the adaxial side of the midrib, there was a band of fibres (Fig. 7). In different specimens, cell walls were of different thicknesses and were more or less lignified. Among the fibres, there were occasional tracheary elements. Adaxial to the fibres were 2–3 rows of cortical parenchyma. In two specimens, *NGF10358* and *BSIP183*, there were inverted vascular tissues on the abaxial side of adaxial fibres. In *NGF10358*, there was a tangentially spread group of inverted tissues and, adaxial to this, 3–4 bundles which were not precisely orientated. In *BSIP183*, there was some merging of inverted tissues which were seen as separate vascular bundles in the petiole.

Large unlignified or weakly lignified parenchyma cells filled the centre of the midrib and, among them, there were groups of large sclereids.

Towards the leaf margins, palisade was reduced and, close to the margin, there were small round parenchyma cells some of which contained tannin. A short distance from the margin, within the mesophyll, there were fibres and small vascular bundles (Fig. 8). Across the width of the leaf, bundles of various sizes had well developed abaxial and adaxial fibre caps. In the largest, fibres were separated from epidermides by 3 or 4 rows



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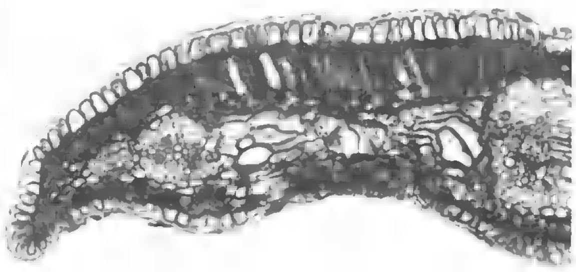

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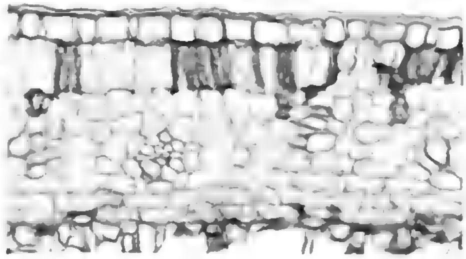

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Fig 7. *Finschia rufa* (*LAE59040*); transverse section of main vein. Main bundles are predominantly collateral with abaxial phloem; there is an abaxial arc of bundles of various sizes, each with an abaxial fibre cap. There is some merging and dividing of fibres and vascular tissues. Adaxial fibres are associated with vascular groups. Bundles are separated by lignified parenchyma cells some of which contain tannin. On the adaxial side of the midrib, there is a band of fibres. (c. × 160).

Fig 8. *Finschia chloroxantha* (*NGF9123*); transverse section of leaf margin. Palisade is reduced towards the margins and, close to the tip, there are small round parenchyma cells some of which contain tannin. A short distance from the tip, within the mesophyll, there are fibres and small vascular bundles. (c. × 80).

Fig 9. *Finschia chloroxantha* (*NGF9123*); transverse section of leaf. Across the leaf, bundles of various sizes have well developed abaxial and adaxial fibre caps. In the largest, fibres are separated from epidermises by 3-4 rows of parenchyma. Near others, palisade is more or less modified. The smallest bundles are within the mesophyll. Large tracheary elements are associated with vascular bundles or occur in groups among mesophyll cells. (c. × 160).

Fig 10. *Grevillea papuana* (*NGF38967*) transverse section of leaf. Some heavily lignified palisade cells, some with irregular ends, intrude among other cells, and resemble columnar sclereids. (c. × 50).

of parenchyma. Near others, palisade was more or less modified. The smallest bundles were within the mesophyll. Large tracheary elements were associated with vascular bundles or occurred in groups among mesophyll cells (Fig. 9).

Finschia rufa

The description below only records features in which *F. rufa* differed from *F. chloroxantha*. The description of *F. chloroxantha* can be used for other features.

Node

Hartley 13201 was a small specimen. One node was examined. At lower levels, in the position of one lateral leaf trace, there were two stelar bundles but these merged before leaving the stele. The specimen collected by *Powell* was larger. There was secondary thickening in the stem and petiole. Several adjacent nodes were examined. In all of them, there was a single stelar bundle associated with each leaf trace.

Petiole

In the material collected by *Powell*, where the petiole was separate from the stem, the abaxial arc contained 25–28 bundles and, in the adaxial line, there were 9 inverted bundles and 3 in which tissues were not precisely delimited and orientated. The arrangement of inverted bundles was similar throughout the petiole.

In *Brass 25899*, near the base of the petiole, there were one or two inverted bundles and one bundle in which tissues were not precisely orientated. Towards the lamina, there was one approximately inverted bundle on either edge of a broad adaxial band of fibres. In *Hartley 13201*, at the distal end of the petiole, inverted vascular tissues were not in collateral bundles; elements were dispersed among fibres and parenchyma.

Transition from petiole to leaf

In the material collected by *Powell*, in the midrib, in the lowest third of the leaf, there were inverted bundles. At higher levels, adaxial vascular tissues were randomly orientated or dispersed.

In *Brass 25899* and *Hartley 13201*, within the leaf, inverted bundles were hardly recognisable.

Leaf

Abaxial epidermal cells were more or less rectangular and were covered with a close pattern of wax granules. Anticlinal walls were hardly sinuous. Especially over veins, on both surfaces, epidermal cells contained tannin.

On the adaxial surface, there were occasional, robust, T-shaped hairs. Over veins, hairs were more numerous.

The basal cells of hairs on the abaxial surface were similar to others in the genus but the two arms of the terminal cell were elongated and a persistent dense indumentum covered the surface.

No glandular hairs were seen in *F. rufa*.

In all the specimens examined, there was a weakly developed second row of square palisade cells.

At the midrib, in *Brass 25899*, there were some 3-4 rows of abaxial cortical parenchyma. There was no distinct, subepidermal layer. There were no inverted bundles. In material collected by *Powell*, in sections from the centres of three leaves, there were occasional vascular elements among adaxial fibres but, in two leaves, there were three or four adaxial amphivasal bundles.

Finschia ferruginiflora

The description below only records features in which *F. ferruginiflora* differed from *F. rufa*.

Petiole

In available material, there were no inverted bundles. Towards the adaxial side, there was a broad band of well lignified fibres. Among the fibres, there were vascular elements.

Leaf

Abaxial epidermal cells were more or less rectangular. Anticlinal walls were hardly sinuous. Nearly all adaxial epidermal cells contained crystals. T-shaped hairs were occasional and often deciduous. Where complete hairs were seen, terminal cells were elongated and their walls were thin. No glandular hairs were found in *F. ferruginiflora*.

In *Manner & Street 255*, there was a single row of tall, narrow palisade cells; some had lignified walls. Ends of cells were irregular and there was evidence of intrusive growth. On both sides of the spongy mesophyll, there were one or two rows of square, regular cells. These characteristics of the palisade and spongy mesophyll were present but not as distinct in *Robbins 817*.

Particularly in *Manner & Street 255*, at the midrib, the subepidermal row of cells was not continuous and distinct and the central parenchyma was well lignified.

Discussion

It was possible to identify the three species in the genus using leaf epidermal features. The epidermal cells on the abaxial leaf surface of *F. chloroxantha* had distinctly sinuous anticlinal walls, whereas those of *F. rufa* and *F. ferruginiflora* were barely sinuous. Among the three species, the covering of wax granules on the abaxial surface was unique to *F. rufa* and glandular hairs were found only in *F. chloroxantha*. T-shaped hairs with elongated terminal cells formed a permanent dense indumentum on the abaxial surface of *F. rufa*. In *F. ferruginiflora*, there were persistent T-shaped hairs with elongated thin-walled terminal cells. The same epidermal features were consistent with the synonymy of *F. rufa* and *F. carrii*.

F. ferruginiflora and *F. rufa* grow in inaccessible habitats and, even in herbaria, specimens are few. It is desirable to examine more material to confirm the consistency of these features.

There were differences in palisade among the specimens examined but variation in *F. chloroxantha* and the plasticity of this feature generally made it inadvisable to attribute taxonomic significance to character states.

There was within-species variability in the node and in the persistent or ephemeral inverted vascular bundles in the petiole and leaf. No nodal material of *F. ferruginiflora* was available and the short length of petiole in *Manner & Street 255* did not include the proximal region. In two specimens of *F. rufa* there were inverted bundles in the petiole but, in the lowest levels of the leaf, the tissues were dispersed. In material collected by *Powell*, inverted bundles were seen in the lowest third of the midrib. In five specimens of *F. chloroxantha*, there were inverted bundles at the proximal end of the petiole but, in material collected by *Powell*, this arrangement of vascular tissues was not seen at the distal end. At the centre of the leaf, inverted bundles were seen only in *BSIP183* and *NGF10358*. Differences in structure were not associated with particular localities in this widely distributed species.

In nodes, modifications in more than one vascular bundle in the positions of some leaf traces might well have been symptoms of the frequent merging and dividing of stelar tissues rather than significant differences in the nodal pattern common to all the specimens examined. This does not necessarily exclude the taxonomic significance of multiple bundles at the generic level.

Finschia differs from *Grevillea* in having indehiscent drupaceous fruits, and *Hakea* is distinguished from *Grevillea* by its heavy follicular fruits, the pericarps of which have secondary thickening formed by cambial activity (McGillivray 1993). McGillivray quoted Weston (pers. comm.) who suggested that these features were derived, and this has been corroborated by unpublished molecular analyses on *Grevillea, Hakea* and *Finschia* (P. Weston pers. comm.). In *Grevillea,* most nodes had three lacunae (Catling & Gates 1998) which raises the question whether the nodes in *Finschia* are apomorphic, having gained traces which gave rise to inverted bundles, or plesiomorphic with other members of the subtribe having lost these tissues. The presence of midribs with multiple bundles (including inverted bundles) is quite homoplasious within the family (Dillon 2002). Of all other species in the subtribe which have been examined (Catling & Gates 1995a, b; 1998) only *Hakea baxteri* and *H. brownii* had nodes in which small stelar bundles were continuous with inverted bundles in the petiole and leaf. Within *Hakea*, these species were in the *Obliqua* group (Barker, 1990). The anatomy of the leaves of these Hakeas was different from the leaf anatomy of *Finschia* (Catling & Gates 1995a). *Hakea* is generally accepted to be derived with respect to *Grevillea.* Even so, *Finschia* shares some anatomical similarities with *Hakea.*

Of 41 specimens of 30 taxa examined in *Grevillea,* there were additional bundles in the node in only two species. In *G. insignis* there were 4 lacunae and 4 traces and, in *G. glauca,* there were two stelar bundles in the position of each lateral leaf trace in two adjacent nodes. In 47 specimens of 31 species of *Hakea,* there were additional bundles in seven species.

In *Hakea,* inverted bundles occurred in the petiole, or leaf base, of 17 specimens of 10 species whilst, in *Grevillea,* they were found only in *G. wickhamii, G. laurifolia, G. insignis* and *G. glauca.* Although some anatomical characteristics of G. *laurifolia* were unlike other species of Group 1 in McGillivray's (1993) classification, taxonomists are convinced that the species is central in this group. Of the specimens examined in the genus, only *G. wickhamii* had inverted bundles in the midrib in sections from the centre of the leaf. In *G. insignis,* there were amphivasal bundles in the midrib complex. Taxonomically, *G. laurifolia, G. wickhamii, G. glauca* and *G. insignis* are not thought to be close to one another or to *Finschia.*

In *Finschia* there was a concentration of sclereids close to the adaxial side of the abscission layer. Similar tissue patterns were found only in *Grevillea insignis, G. sparsiflora, G. acuaria* and *G. pauciflora* and in all the specimens from Groups 7 and 8 of McGillivray (1993) in which a complete node was examined. In *Hakea,* with the exception of *H. linearis,* the feature occurred in all the nodes studied. *G. sparsiflora, G. acuaria* and *G. pauciflora* are recognised to be closely related and have similar anatomy in which several features are different from other species in the genus (Catling & Gates 1998). Group 8 included four species that share some unusual anatomical characteristics with some species of *Hakea* (Catling and Gates 1998). In Group 7, six species of *Grevillea* were examined. *G. robusta, G. meisneri* and *G. papuana* shared similarities, some of which were found in *Finschia. G.robusta* grows in rain forests and along creeks in Queensland and Northern New south Wales. *G. papuana* and *G. meisneri* are endemic to Papua New Guinea and New Caledonia respectively. *G. glauca* grows in Queensland and Papua New Guinea. It differs from other species in the group in having amphistomatic, isobilateral leaves and bundle sheaths which contained silica bodies. In spite of these differences, McGillivray (1993) placed *G. glauca* in this group. Unusually in the genus, but like some specimens of *Finschia, G. glauca* had additional bundles in the position of leaf traces in the node.

In *G. robusta, G. papuana* and *G. meisneri,* leaves were dorsiventral and shared similarities in structure (Catling & Gates 1998) which, in their overall tissue patterns were similar to those in *Finschia.* In *G. papuana,* some heavily lignified palisade cells, some with irregular ends which intruded among other cells, resembled columnar sclereids (Fig. 10). This feature was seen also in *G. glauca* and in *F. ferruginiflora,* it was well developed in *Manner & Street 255.* Columnar sclereids were not found in other species of *Grevillea* but were a consistent feature of *Hakea* (Catling & Gates 1995b) especially in the Needlewoods and in the third sub division of the genus (Barker 1990). Although there were reorientated vascular tissues in the leaf bases of *G. meisneri* and *G. robusta,* the examination of series of sections showed that they were not homologous with inverted bundles in *Finschia.*

This examination of the anatomy of *Finschia* was a part of early studies to investigate some groups of the Proteaceae in which leaf anatomy had not previously been described. Similarities between *Finschia* and some species of *Grevillea,* placed together in Group 7 in McGillivray's (1993) classification, would support the relationships among these taxa proposed by some taxonomists although the distinctly different nodal structure needs some explanation. Similarities shared by *Finschia,* some species of *Hakea* and species such as *Grevillea insignis* and *G. wickhamii* might be significant but it is necessary to study more species and more specimens before proposing hypotheses.

Acknowledgments

The author would like to thank Dr. Kevin Powell, formerly on the staff of the University of Technology, Lae, Papua New Guinea, who collected excellent, invaluable material of *F. chloroxantha* and *F. rufa*; I am most grateful. Also I thank the Director of the Royal Botanic Gardens, Kew, the former Keeper of the Herbarium, Dr Brian Stannard, and Mrs Sandy Atkins who allowed me to use the collections and helped me to find specimens. At the Jodrell Laboratory, Miss Mary Gregory gave me great assistance and Miss Anna Lynch continued to provide valuable literature information. Professor Pieter

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Appendix A. Specimens Examined

Legend: F = ***Finschia***; *G* = ***Grevillea***. Regions examined: 1 = Stem, 2 = Node, 3 = Petiole, 4 = Centre leaf, 5 = Leaf margin

Species	**Collector**	**Location**	**Regions examined**
F. chloroxantha Diels	K. Powell s.n.	Unitech. Campus, University of Technology, Lae, Morobe, PNG	1,2,3,4,5
	K.J. White NGF10358	Oriomo River, Western, PNG	3,4,5
	J.J. Havel & J. Dobson NGF9123	Bulolo, Morobe, PNG	1,2,3,4,5
	Whitmore Collection BSIP5577	Baga Island, New Georgia Group, Solomon Islands	1,2,3,4,5
	R.S. Walker & C.T. White BSIP183	Kolombangara Island, New Georgia Group, Solomon Islands	3,4
	Akorra 238	No locality	4,5
F. rufa Warb.	K. Powell s.n.	Bulolo Forestry College, Morobe, PNG	1,2,3,4,5
	S. Isles LAE59040	S of Manumu village, Central, PNG	5
F. rufa Warb.	Brass 25899	Waikaiuna, Normandy Island, Papuan Islands, PNG	3,4,5
		T.G.Hartley 13201 Near Perosa, c. 18 miles SW of Okapa, Eastern Highlands, PNG	1,2,3
F. ferruginiflora. C.T White	R.G. Robbins 817	Asaro Valley, Eastern Highlands, PNG	4
	H. Manner 225 & W. Street	Jimi valley, Western Highlands, PNG	3,4,5
G. papuana Meisn.	E.E. Henty, R. Isgar & M. Galore NGF38967	Oksapmin, West Sepik, PNG	3,4,5,6

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Goniothalamus amplifolius B.J.Conn & K.Q.Damas (Annonaceae), a new species from Papua New Guinea

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Abstract

The new species of **Goniothalamus amplifolius** B.J.Conn & K.Q.Damas, from the Vanimo area of the West Sepik botanical region (Sandaun Province, Papua New Guinea), is here described, with habitat notes and a botanical illustration. Although the affinities of this species are unclear, it is morphologically similar to *G. grandiflorus*, but differs by its larger leaves and smaller flowers.

Introduction

Goniothalamus (Blume) Hook.f. & Thomson (Annonaceae) is a large palaeotropical genus of more than 130 species (Saunders & Chalermglin 2008). The genus is characterized by mostly axillary, usually pendant, bisexual flowers that consist of three sepals, and six petals arranged in two whorls. The outer whorl of petals is typically larger than the inner whorl, with the latter whorl connivent, forming a mitre-like dome over the numerous free stamens and carpels. The stamens have broad apical connectives and the fruits are apocarpous. The species of *Goniothalamus* that occur in Papua New Guinea are small subcanopy trees that are a frequent component of lowland forests. Prior to the discovery of *Goniothalamus amplifolius*, seven species were commonly recognized as occurring in Papua New Guinea, namely, *G. aruensis* Scheff. (Scheffer 1885), *G. cauliflorus* K.Schum. (Schumann 1889), *G. grandiflorus* Boerl. (Boerlage 1899) and *G. imbricatus* Scheff.(Scheffer 1885) – all common, wide-ranging species; *G. caloneurus* Miq.– only known from Milne Bay region; *G. inaequilaterus* K.Schum. & Lauterb. – recorded from the Finschhafen area, Morobe region, and *G. viridiflorus* K.Schum. & Lauterb.– once collected from near the Ramu River, Madang region (Schumann and Lauterbach 1900).

There have been no recent taxonomic studies of the genus in New Guinea, with recent workers focusing on the species of neighbouring regions: Australia (Jessup 1986), Borneo (Mat-Salleh 2001), Peninsula Malaysia (Saunders 2003), Sumatra, Indonesia (Saunders 2002) and Thailand (Saunders and Chalermglin 2008). The taxonomic status of other names published by Burck (1911), Lauterbach (1905), Lauterbach and

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Schumann (1898), Schumann and Lauterbach (1900) for the species occurring in the New Guinea region is poorly understood. A review of the genus in this region is urgently required.

The Papua New Guinean botanical regions cited in this paper follow Womersley (1978). The use of the term 'podium' for pedicellate flowers follows Conn (1995).

Goniothalamus amplifolius B.J.Conn & K.Q.Damas, ***sp. nov.***

a *G. grandifloro* (Warb.) Boerl. foliis longioribus (100–120 cm) latioribusque (7–13 cm), costis petiolisque robustioribus, floribus brevioribus, petalis interioribus 20–25 mm longis differt.

Type: Papua New Guinea: West Sepik: near Vanimo, *K.Q. Damas LAE79249*, 31 Aug 1994 (holo: LAE289781; iso BRI, K, L, NSW, NY).

Small tree, up to 5 m high, usually single-stemmed, bearing distinct leaf scars. Leaves simple, alternate; petiole 3–3.5 cm long, swollen (pulvinate), up to 1.5 cm thick, abaxially convex beneath lamina, adaxially grooved; lamina narrowly oblong to narrowly obovate, 100–110(–120) cm long, 25–30(–35) cm wide (length to width ratio 3.3–4), abaxial surface finely puberulous, adaxial surface glabrous; base rounded, very shortly subcordate; margin entire; apex shortly and indistinctly acuminate (acumen c. 4 mm long) to subobtuse; midrib straight, stout, raised and prominent on abaxial surface, grooved on adaxial surface, especially towards base, almost flattened distally; secondary veins distinct and prominent, especially on abaxial surface, grooved adaxially, up to 27(–30) pairs, arising at an angle of 45–50 degrees to midrib; tertiary veins percurrent. Inflorescence cauliflorous; flowers in raised clusters, podiate (podium 20–25 mm long); bracts, inserted at base of podium, broadly ovate, distal bract largest (c. 3 mm long, c. 2.5 mm wide). Sepals 3, brownish green, almost half-way connate, each sepal triangular, c. 8 mm long, margin entire, apex obtuse to subacute, inner and outer surfaces densely covered with variously appressed, antrorse, or spreading, rusty red hairs 0.1–0.2 mm long. Petals arranged in 2 whorls; outer petals 3, brownish green, narrowly ovate, 40–50 mm long, 11–12 mm wide near base (length to width ratio 3.6–4), 3–4 mm thick, margin entire, apex tapering, incurved on distal half, densely hairy as for sepals; inner petals 3, valvate, connivent, broadly ovate to slightly rhombic, 20–25 mm long, 20–25 mm wide (length to width ratio c. 1), 1.5–2 mm thick, concave, slightly incurved, densely hairy (hairs ± patent, 0.1–0.2 mm long). Stamens many, spirally arranged, flattened-oblong, 3–4.2 mm long, connectives pulvinate at apex, concealing anthers. Gynoecium apocarpous, glabrous; carpels many, c. 50, slightly asymmetrically fusiform, 3–3.5 mm long, with longitudinal groove ventrally; style very short, slightly incurved; stigma indistinct, ligulate to subcylindrical, c. 2.5 mm long. Fruit of separate fleshy carpels; mature carpels (apocarps) fusiform to ellipsoidal, dark reddish brown, glossy, 60–70 mm long, 20–22 mm diameter, base tapering; stipe 6–8 mm long, c. 7 mm diameter (basally), glabrous; seeds 6–7 per carpel, flattened ovoid, 10–12 mm long, glabrous. Figures 1 & 2.

Distribution: only known from Pasi Forest area, near Vanimo, West Sepik (Sandaun Province), Papua New Guinea.

Habitat: this is a common, albeit scattered species occurring in Closed Lowland Rainforest, at an elevation of about 200 m.

Notes: a comparison of the morphology of the following three common species of

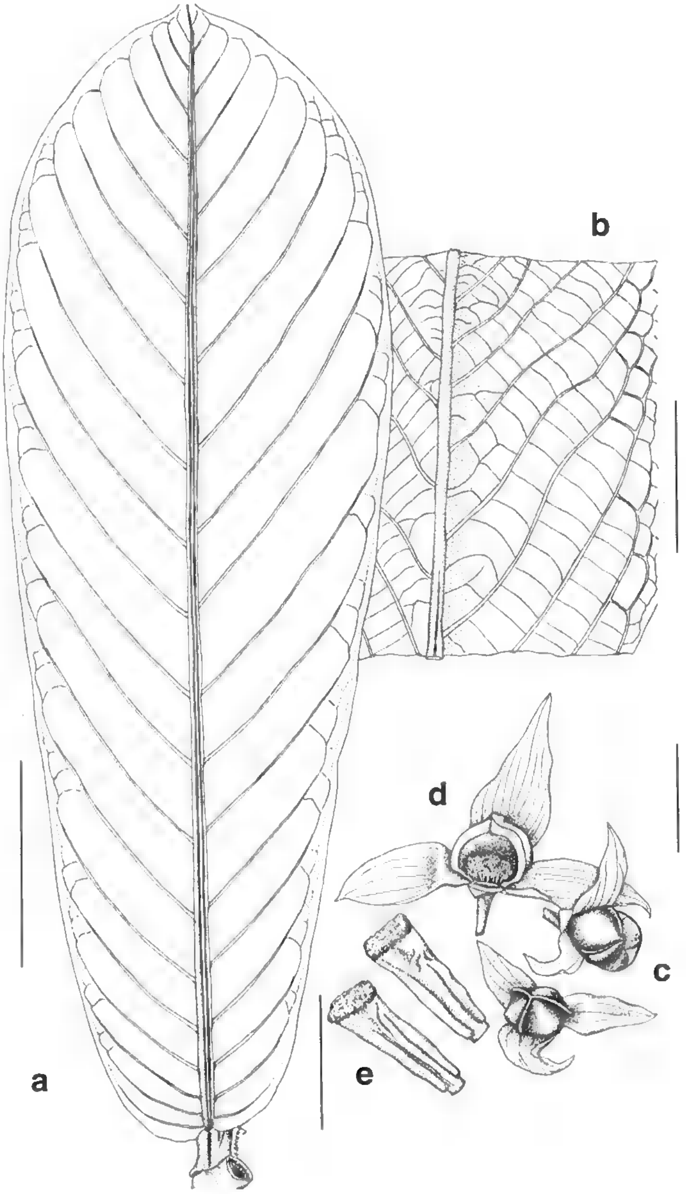

Fig.1. *Goniothalamus amplifolius* B.J.Conn & K.Q.Damas. **a,** adaxial surface of leaf showing petiole, lamina, and primary and secondary venation; **b,** detail of abaxial leaf lamina showing percurrent tertiary veins; **c,** 2 complete flowers showing 3 outer petals and 3 inner petals permanently connivent distally to form a mitre-like dome over reproductive organs; **d,** flower showing 3 outer petals, with one proximal inner petal removed to show androecium and gynoecium; and **e,** detail of two stamens. Scale: a & b = 20 cm; c = 50 mm; d = 30 mm; e = 4 mm. All from *Damas LAE79249*.

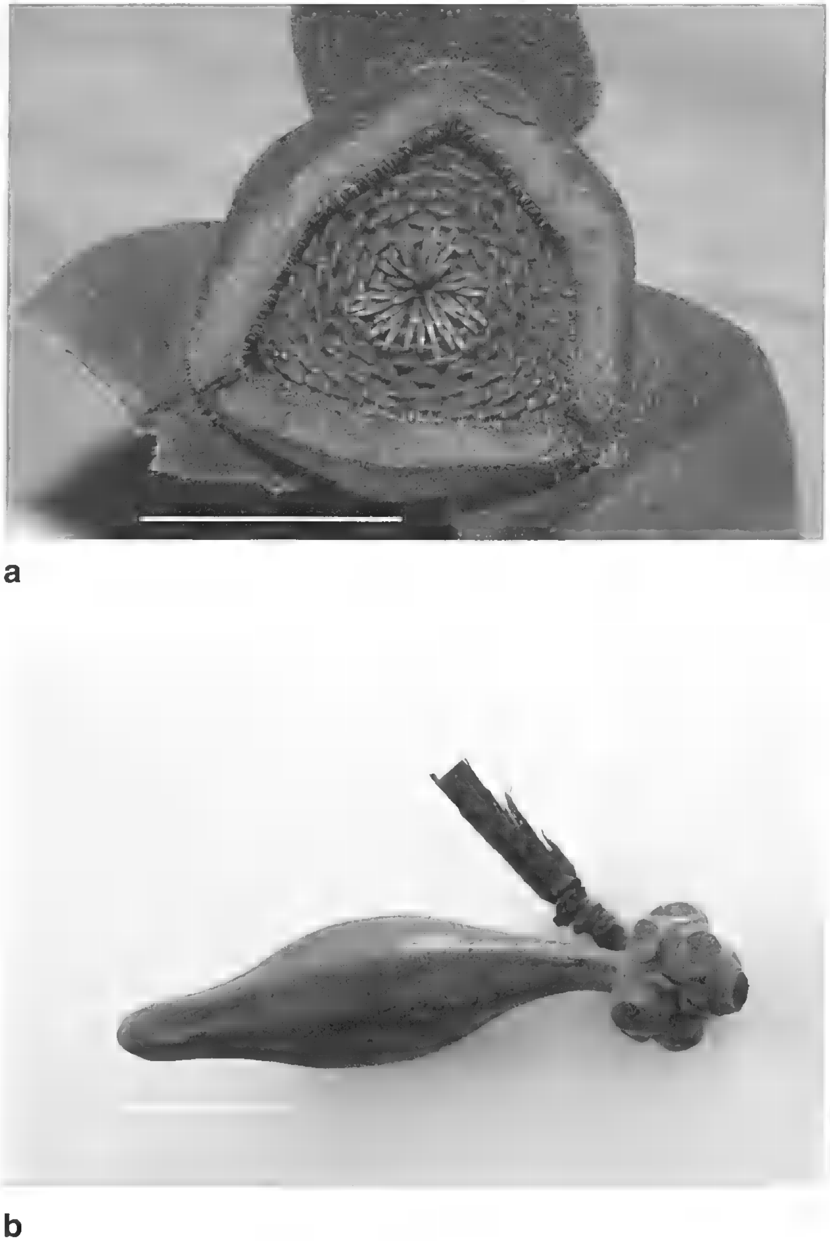

Fig. 2. *Goniothalamus amplifolius* B.J.Conn & K.Q.Damas. **a,** distal half of inner corolla removed to revealed a top view of stamens surrounding gynoecium, with stigmas visible. Scale bar = 10 mm; **b,** single, sessile fruiting apocarp attached to enlarged receptacle, other apocarps removed. Scale bar = 25 mm.

Goniothalamus in Papua New Guinea with *G. amplifolius* is based on direct field observations, evaluation of herbarium collections at LAE and NSW, and information included in the protologues (see references cited in the 'Introduction,' above). *Goniothalamus amplifolius* has leaves 100–110(–120) cm long, 25–30(–35) cm wide) whereas, those of *G. grandiflorus* are (16–)20–35(–50) cm long, 7–12(–13) cm wide, with the other common Papua New Guinean species, *G. aruensis* having leaves of a similar size to the latter species (16–30 cm long, (5–)7–12 cm wide). The outer petals of all three species are possibly similar in length (*G. amplifolius*: 40–50 mm long; *G. grandiflorus*: 20–40(–50) mm long; *G. aruensis*: 17–40(-50) mm long). *Goniothalamus amplifolius* has longer inner petals than *G. grandiflorus* (20–25 mm long and c. 17 mm long, respectively). Differences in fruit size suggest that *G. amplifolius* and *G. grandiflorus* have larger fruits (60–70 mm long, 20–22 mm diameter and c. 80 mm long, c. 40 mm diameter, respectively), whereas, the fruits of *G. aruensis* are smaller, 30–50 mm long and 10–15 mm diameter.

Goniothalamus cauliflorus and *G. imbricatus* are also both widespread species of lowland forests. However, both species are readily distinguished from *G. amplifolius*. *Goniothalamus cauliflorus* has laminas that tend to have fewer secondary veins (8–11 cf. up to 27(-30) pairs of secondary veins in *G. amplifolius*), and shorter outer and inner petals (c. 9 mm long and c. 5 mm long, respectively), whereas in *G. amplifolius* outer petals are 40–50 mm long and inner ones 20–25 mm long. *Goniothalamus imbricatus* has leaves with a long-attenuate base (*G. amplifolius* with base of lamina rounded), carpels 6–9 (*G. amplifolius* at least 50) and seeds orbicular and 2–5 per apocarps (*G. amplifolius* with seeds flattened ovoid and 6–7 per apocarps). Morphological comparisons with other published names must await a more detailed review of the genus in New Guinea.

Acknowledgments

We thank Thomas Bilalu (previously Papua New Guinea Forest Research Institute, Lae) for drawing our attention to this species; Armstrong Bellamy (University of Technology Lae, Bulolo University Campus, Papua New Guinea) prepared the illustration of *Goniothalamus amplifolius* for publication; and Peter Wilson (NSW) kindly corrected the Latin diagnosis. Elizabeth Brown and Jaime Plaza (both NSW) kindly provided the photographs for figure 2a and b, respectively. We thank the anonymous referees for providing detailed advice that has significantly improved this paper.

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Typification of some names in *Eucalyptus* (Myrtaceae), Part 3

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Abstract

Twelve names in *Eucalyptus* are here lectotypified, and the typification is clarified for a further three names. The species involved are indigenous to eastern Australia. Full discussion of relevant type specimens is given, and other nomenclatural notes are included.

Introduction

The first and second papers in this series (Bean 2009; Bean, in press) dealt with the typification of 29 current names in *Eucalyptus*. This paper deals with a further 15 current names, viz. *E. abergiana, E. aggregata, E. amplifolia, E. baileyana, E. brevifolia, E. coccifera, E. consideniana, E. elata, E. fraxinoides, E. globulus* var. *pseudoglobulus, E. gunnii, E. johnstonii, E. pellita, E. perriniana* and *E. urnigera*. 12 names are lectotypified, while for three names the typification is clarified or corrected. The species treated herein are indigenous to eastern Australia, and have been chosen after detailed examination of the nomenclature information in the protologue and in subsequent publications.

These typifications are necessary to provide a unique type specimen for each name, thereby fixing the application of the name. Nomenclatural information offered by Chippendale (1988), Hill and Johnson (1998), Hill (2002-04) and Slee et al. (2006) is discussed, especially where it differs from the view expressed here.

The species are arranged alphabetically by the basionym.

Typification

Eucalyptus abergiana F.Muell., Fragm. 11: 41 (1878) [= *Corymbia abergiana* (F.Muell.) K.D.Hill & L.A.S.Johnson, *Telopea* 6: 244 (1995)].

Type citation: "In vicinia sinus Rockingham's Bay ad montes; Dallachy". **Lectotype** (Chippendale 1988, p. 97): Queensland. Rockingham Bay, *J. Dallachy 21,* 24 March 1867 (MEL1616369; isolecto: NSW306297).

Specimens collected from Rockingham Bay by John Dallachy are present at MEL, NSW

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and K, with two sheets at each of these herbaria. These sheets are from at least two gatherings. One of the sheets at NSW (NSW306298) has a label written by Dallachy with the date 1 August 1867. One of the sheets at MEL also has an original Dallachy label, but with the date 24 March 1867, while the second sheet (MEL1616368) is undated.

Chippendale (1988) cited the type as "T: Rockingham Bay, Qld, 24 Mar. 1867, J. Dallachy 21; holo: MEL; iso: K, NSW." In so doing, he has effectively lectotypified the name using the sheet at MEL with this date (MEL1616369). Dallachy's label includes the number "21" in his handwriting, seemingly a collection number. NSW306297 also includes the number 21, and so this sheet can reasonably be designated as an isolectotype. It is not possible to firmly link either of the specimens at K to the lectotype, either from the plant material present, or from details on the labels, and so these should not be regarded as isolectotypes.

Eucalyptus aggregata H.Deane & Maiden, Proc. Linn. Soc. New South Wales 24(4): 614 (1900).

Type citation: "Wallerawang (H.D.); Rydal (J.H.M.); Jenolan Caves (W. Blakely); near Orange, on the Cadia–road, which remains its most western locality at present (R.H. Cambage); Rockley and Burraga (R.H.C.). It has not been recorded north of Sydney, and its southern localities are Nimbo Station, head of the Queanbeyan River; also Crookwell (H.D.) and Fagan's Creek, Braidwood district (Mr. W. Bäuerlen, communicated by Mr. R.T. Baker)." **Lectotype (here designated):** New South Wales. Wallerawang, *H. Deane s.n.*, October 1886 (NSW313030; isolecto NSW313029).

The initials "H.D." mentioned in the type citation refer to Henry Deane. Maiden (1915: 100) stated in a figure caption "7*a*. Small juvenile leaves; 7*b*, fruits. Wallerawang, N.S.W. (J.H.M.) Both from the type." Chippendale (1988) accepted this as a lectotypification of the name. However, Maiden's statement does not validly lectotypify the name because the Wallerawang specimen cited in the protologue was collected by Henry Deane, not by J.H. Maiden. It does however indicate that Maiden considered Wallerawang to be the type locality. To validate his concept, a sheet collected by H. Deane from Wallerawang (NSW313030) is here chosen as the lectotype. The specimen matches the protologue and is of good quality. It comprises pressed unmounted branchlets bearing adult leaves, flower buds and mature fruits. A second sheet of lesser quality from the same gathering (NSW313029) is an isolectotype.

Eucalyptus amplifolia Naudin, Descr. Emploi Eucalyptus introd. Europe, 2nd Memoire 28 (1891).

Type citation: "Je l'ai trouve dans plusiers endroits de l'Algerie, dans nos jardins de Provence, dans celui de M. Hanbury, a la Mortola, pres de Menton; j'en ai recu des echantillons de M. Ricasoli, de Florence et nous en possedens plusiers exemplaires de differents ages a la villa Thuret". **Lectotype (here designated):** Algeria. Bois du Bologne, *C. Naudin s.n.*, undated (P, 1st sheet cited below; isolecto: P, 2nd sheet cited below).

The lectotype is mounted on two sheets, and comprises four mounted branchlets with adult leaves and mature fruits. The first sheet bears a label in Naudin's handwriting saying "Eucalyptus amplifolia Ndn./ du Bois de Boulogne d'Alger, administration forestière/ Ch. Ndn.", and a determinavit slip by J.H. Maiden with the name "Euc. tereticornis, Sm. var. latifolia", dated May 1903. It is also stamped "Reçu en Mars 1890", confirming that the material was collected before publication of the name. The label of the second sheet says "Eucalyptus amplifolia Naud./ Bois de Boulogne [...] Alger/

Ch. Naudin".

Eucalyptus baileyana F.Muell., Fragm. 11: 37 (1881).

Type citation: "Ad sinum marinum Moreton-Bay rara; Bailey". **Lectotype** (Chippendale 1988, p. 117): Queensland. Coopers Plain, *F.M Bailey s.n.*, June 1878 (MEL1606591, possibly holo).

There are two relevant sheets at MEL that were collected by F.M. Bailey. MEL1606591 comprises some mounted branchlets bearing adult leaves, two mature fruits attached to a leafless branchlet, and some strips of bark and wood. This sheet is in accord with the protologue and is original material. Accompanying this sheet is a letter from Bailey to Mueller saying that he considered this to be a new species, and giving details on its morphology and supposed affinities. Bailey also stated that "the flowers are not out as yet …".

The second sheet (MEL1607734) bears some fruits in a packet, some of which have been cut in transverse section. This sheet bears two labels written by Bailey. One of these states (in part) "Eucalyptus Baileyana FvM/ In Fragmt 89 you say that you have not seen the seed…". Bailey has cited the published name and has clearly seen the issue of *Fragmenta* in which it was published. Hence MEL1607734 post-dates the publication of the name and is not original material.

Chippendale (1988) cited "T: near Moreton Bay, Qld, Jun 1878, F.M.Bailey s.n.; holo: MEL; iso: NSW." This constitutes a valid lectotypification as the date is sufficient to specify the sheet at MEL to which he was referring. Under Article 9.8 (McNeill et al. 2006), his use of the term "holotype" is correctable to "lectotype". Hill (2002-04) cited the type in that way, i.e. (lecto: MEL, isolecto NSW, BRI, K).

Hill & Johnson (1998: 408) cited "Type: Qld. near Moreton Bay, F.M. Bailey s.n., 1869 (holo: MEL; iso: NSW, BRI, K)". The material at NSW is a mixture of two species, and is distributed on two sheets. The fruits on these sheets belong to *E. baileyana* as described in the protologue, but the leaves, buds and flowers belong to *E. tindaliae* Blakely. The fruits could be part of the original gathering by Bailey, as they are similarly attached to a leafless branchlet, but it is impossible to say. The non-fruiting material is not original material as it bears open flowers. Mueller stated in the protologue that he had not seen flowers, with the words "flores statu evoluto nondum me visi".

There are two sheets at K that bear material remarkably similar to that at NSW i.e. fruits of *E. baileyana* attached to leafless branchlets, and flowers buds and leaves of *E. tindaliae* (although identified by M.I. Brooker as '*E. ?laevopinea*').

The specimen at BRI considered by Hill and Johnson (1998) to be a type is probably AQ 055285. It was collected from "Eight Mile Plains" and is obviously an old specimen, and has been marked as a "Co-type" in the handwriting of C.T. White. There is no writing by Bailey on the label and indeed no evidence that it could be original material. It is here concluded that the material at NSW, K, and BRI should not be considered isolectotypes.

The lectotype (MEL1606591) is the only indisputable extant type material that is known for *E. baileyana.*

Eucalyptus brevifolia F.Muell., J. Proc. Linn. Soc., Bot. 3: 84 (1859).

Type citation: "In eremis terrae tabularis ad flumina Victoria et Sturt's Creek, in plaga

Arnheim's Land et circum sinum Carpentaria." **Type:** "Victoria R., stony ridges, May 1856, *F. Mueller* (K, MEL, BRI)", *fide* Blake (1953), p. 272. **Lectotype (here designated):** Northern Territory. Victoria River, stony ridges, *F. Mueller s.n.*, May 1856 (K000279690; isolecto: BRI [AQ103085], MEL231974).

Blake (1953) gave a comprehensive discussion on the nomenclature of *E. brevifolia* and *E. pallidifolia* F.Muell., showing that both of these names are applicable to the same species. He typified *E. brevifolia*, but cited specimens from three herbaria. Under the provisions of Art. 9.15 (McNeill et al. 2006), the initial lectotypification of Blake (1953) is here narrowed to the K specimen, as it is of much better quality than the material at MEL and BRI. The MEL and BRI specimens become isolectotypes.

The lectotype is of good quality and has two pressed and mounted branchlets, one bearing adult leaves and numerous mature fruits, and the other bearing adult leaves and immature buds. There are also a few fruits mounted separately in the corner of the sheet.

Eucalyptus coccifera Hook.f., London J. Bot. 6: 477 (1847).

Type citation: "Hab. Tops of mountains: Lawrence, Gunn." **Lectotype (here designated):** Tasmania. Mt Wellington, *R.C. Gunn 1076*, 30 October 1840 (K000347508; isolecto NSW334881).

There are specimens mounted on four sheets at K that can confidently be considered original material. On one sheet is a collection by R.W. Lawrence, and material on the other three sheets was collected by R.C. Gunn. J.D. Hooker added the epithet *coccinellifer* to the label of Lawrence's specimen, obviously inspired by his mention of "a species of *Coccus*" that grew on the tree. Hooker later amended the epithet to *coccifera*.

The specimen chosen as lectotype consists of two pressed and mounted branchlets, one bearing adult leaves and mature fruits; the other bearing adult leaves and flower buds. The buds are apparently close to maturity, but no open flowers are evident. There is no reason to suspect that these two branchlets are not part of the same gathering. The lectotype matches the description in the protologue. The other Gunn collections of *E. coccifera* are not isolectotypes because the collection dates are different. NSW334881 has an original Gunn label with details exactly matching the lectotype, hence it is an isolectotype.

Eucalyptus consideniana Maiden, Proc. Linn. Soc. New South Wales 29: 475 (1904).

Type citation: "Mr Deane and I first collected it near Springwood in 1888. I have received it during the last four or five years from the following localities – Pigeon House Mountain, near Milton; grows to within 100 feet of the top, on sandy, rather barren soil; also sandy ground at Burrill, Ulladulla (R.H. Cambage); Wingello (J.H. Boorman); top of mountain east of Burragorang (R.H. Cambage); Penang Mountain (A. Murphy)." **Lectotype (here designated):** New South Wales. top of mountain east of Burragorang, *R.H. Cambage 1022*, 11 November 1901 (NSW335808).

Most of the specimens that match the type citation are extant at NSW. Maiden (1908) cited in a figure caption "3c. fruits of type. Pigeon House, Milton, N.S.W. (R.H. Cambage)". This does not constitute a valid lectotypification, because there are two gatherings (December 1899 and 31 December 1902) at NSW matching this citation.

A specimen at NSW collected from east of Burragorang by Cambage, and cited in the protologue is chosen here as the lectotype. It is a very good quality specimen and is in full accord with the description given in the protologue. It comprises a pressed unmounted branchlet bearing adult leaves, mature buds, flowers and mature fruits. The material of the lectotype is more complete and diagnostic than that of other specimens cited in the protologue, including the two gatherings from Pigeon House.

Eucalyptus elata Dehnh., Cat. Horti Camald. 26 (1829).

Type citation: "colitur in Horto Camaldulensi". **Lectotype (here designated):** [Italy]. ex Hortus Camalduli, *F. Dehnhardt s.n.*, undated (RO; isolecto: NAP).

German gardener and botanist Freidrich Dehnhardt described this species in 1829, based on a cultivated plant grown in the garden of the Duke of Camalduli's estate near Naples in Italy.

The protologue provides a detailed description, including "bark smooth … branches hanging down … operculum hemispherical, mucronulate … lower leaves opposite, sub-sessile … flowers very numerous, crowded, umbellate, umbels axillary". No specimens were cited in the protologue. A prolonged search for original material has revealed relevant specimens at RO, NAP and W. High quality images of all specimens have been examined by the present author. In the case of W, the digital herbarium was used (Anon. 2006+).

The single specimen at RO bears two old labels. One reads "Eucalyptus elata Dehnt/ ab ipso auctore", in the handwriting of V. Cesati (according to Agostini (1958)). Cesati's notation indicated the second label which, in Dehnhardt's handwriting, reads "E. elata D.", under which someone else has written "Dehnhardt! Ex H. Camaldul.". The second label confirms the origin of the specimen as the garden of the Duke of Camalduli's estate near Naples. This specimen comprises three mounted branchlets bearing mature leaves, clusters of mature buds, and open flowers. This specimen is here selected as the lectotype.

The two specimens at NAP are unmounted and each has two labels, one in the handwriting of Dehnhardt and one written by G. Gussone (according to Agostini (1958)). The first specimen comprises a single branchlet bearing adult leaves, mature buds and open flowers, and is so similar to the lectotype that it is very likely part of the same gathering. The label includes the notation "cult. Camal." Unfortunately this specimen has been severely damaged by insects. The second specimen comprises juvenile leaves and two detached umbels of buds close to maturity. The label mentions the locality of "Portico" which is close to Naples.

There are *Eucalyptus* specimens on six sheets at W that are labelled as being from the Hortus Camaldulensis or Naples and are attributed to Dehnhardt. Two of these sheets (W21344, W21346) do not match the protologue, and belong to another species. One sheet (W21347) bearing mature fruits is at odds with the protologue because fruits are not mentioned. The other three sheets (W21342, W21343, W21345) could all be original material. These specimens comprise mounted branchlets with adult leaves, sessile to subsessile intermediate leaves and immature buds. On the original label for W21342 and W21343 is written "C.h.V. e [...] neapol. a Dehnhardt" by a person unknown, while the original label for W21345 has "Eucalyptus elat" in Dehnhardt's handwriting, under which someone else has written "Hort. Camaldul. Dehnhardt". While these three W specimens are probably original material, they are clearly from a different gathering when compared to the material preserved at RO and NAP, because of the presence of sessile to subsessile intermediate leaves on the fertile branchlets and immature flower buds only.

The RO specimen is here chosen as the lectotype for the name as it is of very good quality, it matches the protologue, and it has a label stating "E. elata D." in Dehnhardt's handwriting. The first mentioned specimen at NAP is considered an isolectotype.

Eucalyptus fraxinoides H.Deane & Maiden, Proc. Linn. Soc. New South Wales 23: 412 (1898); *E. virgata* var. *fraxinoides* (H.Deane & Maiden) Maiden, Forest Fl. New South Wales 3: 87 (1907).

Type citation: "On high mountain ranges of the extreme southern part of New South Wales. Herbarium specimens collected by W. Bäuerlen and the authors on Tantawangalo Mountain (3,000 feet) near Cathcart". **Lectotype** (Maiden (1920), p. 299): New South Wales. Tantawanglo Mountain, *H. Deane & J.H. Maiden s.n.*, December 1896 (NSW26878).

The protologue mentions specimens collected by Deane and/or Maiden, and also specimens collected by William Baeuerlen. Three relevant specimens are present at NSW and one at BM.

Maiden (1920) stated "Tantawanglo Mountain (Henry Deane and J.H.M., 1896). The type." This statement constitutes a valid lectotypification. There is only one specimen matching the protologue that was collected by Deane and Maiden in 1896, namely NSW26878.

The lectotype comprises pressed unmounted branchlets bearing adult leaves, very immature flower buds and mature fruits, and there is also a strip of bark.

Chippendale (1988) failed to recognise the lectotypification by Maiden, and recorded three syntypes for this name. This was followed by Slee *et al.* (2006) and Nicolle (2006).

Eucalyptus globulus* var. *pseudoglobulus Naudin, Descr. Emploi Eucalyptus introd. Europe, 2nd Memoire 34 (1891); *E. pseudoglobulus* (Naudin) Maiden, Crit. Revis. Eucalyptus 8: 28 (1929); *E. globulus* subsp. *pseudoglobulus* (Naudin) J.B.Kirkp., J. Linn. Soc., Bot. 69: 101 (1975).

Lectotype (here designated): France. Villa Thuret, *Naudin s.n.*, undated (P).

In a treatment of *Eucalyptus globulus*, Naudin (1891) included the following paragraph: "*Nous ne lui connaissons jusqu'ici qu'une seule variété, celle qui a reçu le nom de pseudo-globulus, qui ne se distingue du globulus ordinaire que par le volume de ses fruits, de trois ou quatre fois plus petits que ceux du type commun. Il y a d'ailleurs tous les passages entre les extremes de volume*". This constitutes valid publication of the name *E. globulus* var. *pseudoglobulus* by Naudin, because he made a morphological distinction between it and the typical form, and he specified varietal rank.

Naudin did not cite any specimens in the protologue. Chippendale (1974) referred to four specimens that he photographed at P, and which he considered were original material. The present author has examined these photographs, and has chosen a lectotype from them. The chosen specimen comprises a single sheet with a mounted branchlet bearing adult leaves and several clusters of mature fruits. The label of this specimen is in the handwriting of Charles Naudin and reads "Eucalyptus globulus Labill. var. pseudo-globulus, [...] microcarpa/ fruits 5 à 6 fois plus petits qui dans les variétés à gros fruits/ Villa Thuret/ Ch. Ndn." A printed "Herb. Mus. Paris" label states that the specimen was received from Charles Naudin in 1890. This specimen was photographed by G. Chippendale in 1973, and the Negative number 686 appears in the top-left corner of the photo.

Maiden (1929) recognised *E. pseudoglobulus* at species rank, and attributed Naudin as its author. The correct author citation is "(Naudin) Maiden", as Maiden effectively raised Naudin's variety to species rank.

Kirkpatrick (1975) described *E. globulus* subsp. *pseudoglobulus*. He designated "Metung, 23 August 1909, *J.L. King s.n.* (NSW)" as the lectotype. The basionym of this name is *E. globulus* var. *pseudoglobulus* Naudin, published in 1891. Kirkpatrick's choice of lectotype is invalid, as it is not original material.

Eucalyptus gunnii Hook.f., London J. Bot. 3: 499 (1844).

Type citation: "on the elevated tablelands of the interior of Tasmania, especially in the neighbourhood of the lakes (Gunn. n. 1084, 1080, 1082)". **Lectotype (here designated):** Tasmania. Lake Arthur, *R. Gunn 1084/1842,* 18 February 1843 (K000279739; isolecto: NSW314848, possible isolecto: BM).

At K, there is plant material collected by Gunn and mounted on five sheets, and probably all of this material was available to Hooker when drawing up his description.

Gunn's "collection" numbers are in fact taxon numbers, i.e. he gave a constant number to every species he recognised (Haegi 1982; Buchanan 1988). While all of the material on the five sheets belongs to the same currently recognised taxon, Gunn evidently recognised differences within it, and used the numbers 1080, 1082, and 1084 for them. Clearly then, Gunn's '1080' would have been from a different tree to his '1084' or '1082' and hence a separate gathering. It is difficult to know how many gatherings were involved, but the minimum is five, involving various combinations of the dates '18/2/43', '18/2/42' and 'March 1840', and taxon numbers '1080', '1082' and '1084' written by Gunn on various labels.

The protologue includes descriptions of buds, flowers and fruits, hence it is not possible to exclude any specimen because it bears a structure not mentioned in the protologue. A specimen with an original Gunn label from Lake Arthur has been chosen as the lectotype ("lakes" are mentioned in the protologue). It comprises a single branchlet with adult leaves, mature buds and open flowers. This branchlet has the accession number K000279739 separate from other material mounted on the same sheet.

NSW314848 has an original Gunn label with details matching the lectotype. From the locations and dates provided by Chippendale (1974) for *E. gunnii* material present at BM, it is likely that some of the BM material is of the same gathering as the lectotype, and could be reliably designated as isolectotype.

Eucalyptus johnstonii Maiden, Crit. revis. Eucalyptus 6: 280 (1922); *E. muelleri* T.B.Moore, Pap. & Proc. Roy. Soc. Tasmania for 1886: 207 (1887), *nom. illeg. non* Miq. (1856).

Type citation: "on a saddle of the dividing range between the Huon and Derwent watersheds". **Lectotype (here designated):** Tasmania. Mt Wellington, 2000' and lower, *T.B. Moore s.n., anno* 1886 (MEL1610541; isolecto: MEL1610560).

There are two specimens at MEL collected by Moore and matching the protologue.

In a letter to Ferdinand von Mueller, Moore said that "The tree was first met with on a saddle of the Mt Wellington range, due north and south from the two townships [New Norfolk and Victoria]". However in the protologue, he did not use the term "Mt Wellington range", but merely wrote "dividing range". This explains the discrepancy between the type citation and the label of the lectotype.

The lectotype consists of two pressed and mounted branchlets, one bearing adult leaves and mature fruits; the other bearing adult leaves and flower buds. The buds are apparently close to maturity, but no open flowers are evident. The lectotype matches the description in the protologue. The isolectotype bears only adult leaves and flower buds.

Eucalyptus pellita F.Muell., Fragm. 4: 159 (1864); *E. resinifera* var. *pellita* (F.Muell.) F.M.Bailey, Syn. Queensl. Fl. 179 (1883).

Type citation: "Ad sinum oceanicum Rockingham Bay. Dallachy." **Lectotype (here designated):** Queensland. Rockingham Bay, *J. Dallachy 128*, 5 June 1864 (MEL1611097; isolecto: MEL1611096, probable isolecto: K000279538).

The date of publication for *Eucalyptus pellita* was November 1864 (Chapman 1991). Mueller, in the protologue did not describe flower buds, and he stated that he had not seen flowers.

There are four sheets at MEL collected by John Dallachy that have been annotated as type material by previous workers. One of these (MEL1611094) can be excluded because it was collected after the publication date, and another (MEL231894) can be excluded because it bears mature flower buds.

The remaining two sheets at MEL are considered to be part of the same gathering. MEL1611097 has branchlets with adult leaves, and a single fruit in a fragment packet. It has a label in Dallachy's hand that reads as follows: "June 5 June 1864/ A beautiful gum 40 to 50 feet high/ bark rough dark grey/ wood very hard red in centre/ foliage dark green/ no flowers/ the tree was cut down to make a new pole for the dray/ 128". Below that, written in Mueller's hand is "Eucalyptus pellita FvM". This sheet is here designated as the lectotype. MEL1611096 bears branchlets with adult leaves and a cluster of mature fruits, while the label says "Rockingham Bay" in Mueller's hand. It is an isolectotype.

A sheet at K (K000279538) has leaves similar to the lectotype and fruit of the same size and stage of maturity, and it is probably an isolectotype. Another sheet at K (K000279539), also collected by Dallachy, bears mature buds and flowers. Therefore it is not original material.

Eucalyptus perriniana Rodway, Pap. & Proc. Roy. Soc. Tasmania for 1893: 181 (1894).

Lectotype (here designated): Tasmania, north of Hamilton, *L. Rodway s.n.*, May 1892 (HO 16178).

The protologue states "It is a eucalypt that has long been known in the Hamilton… district", and "the kindness of Rev. Mr. Dicker and Superintendent Hedberg has placed at my disposal various specimens at different stages".

There is no original material of *E. perriniana* at K or BM (Chippendale 1974; J. Bruhl, pers. comm.). However, there are two specimens at MEL and one at HO that mention "Hamilton" as the locality and predate the publication of the name. Leonard Rodway is attributed as the collector for all of these specimens. There are no relevant specimens attributed to Hedberg or Dicker in any of the herbaria mentioned.

MEL1611947 has mounted branchlets bearing sessile connate leaves and petiolate leaves with a few fruits attached, and there is a fragment packet containing numerous detached fruits and leaves. An accompanying letter from Rodway to Mueller is dated "Oct 1/ 92". MEL1611948 has two mounted branchlets, one bearing sessile connate leaves and the other bearing petiolate leaves with spent flowers. The accompanying letter from Rodway to Mueller is dated "Apr 27 / 92". HO16178 bears pressed and mounted branchlets of both connate juvenile and petiolate adult foliage, the latter with fruits attached. There is also a fragment packet containing some fruits and two spent flowers. The HO specimen is here chosen as the lectotype. Judging by the dates on the MEL specimens, neither is an isolectotype.

R.L. Rodway gave the first description of the species in 1894. Baker & Smith (1913) redescribed *E. perriniana* in more detail, and claimed authorship for themselves. Rodway's description is rather informal, but is certainly sufficient for valid publication of the name, hence the naming by Baker & Smith is superfluous and illegitimate.

An alternative authorship for *E. perriniana* is "F.Muell. ex Rodway". In the protologue, Rodway mentioned that Mueller had given it the epithet of '*perriniana*'.

Eucalyptus urnigera Hook.f., London J. Bot. 6: 477 (1847).

Type citation: "Hab. Mt Wellington and Lake Echo; Gunn." **Lectotype (here designated):** Tasmania. Mt Wellington, *R.C. Gunn 1074/1842,* 9 February 1839 (K000279742; isolecto: BM000796087, NSW313892, NSW313894).

There are six sheets at K that have been attributed to Gunn, and were collected at either Mt Wellington or Lake Echo. All of these are original material.

Gunn's collection numbers are actually species numbers, and these are sometimes associated with a year (in this case 1842), this being the year of shipment (Buchanan 1988).

The lectotype consists of four pressed branchlets mounted on one sheet, bearing adult leaves with either mature fruits or flower buds. The buds are apparently close to maturity. Two open flowers attached to a peduncle, but unattached to any branchlet, are mounted separately. There is no reason to suspect that all of this material is not part of the same gathering. The lectotype has an original Gunn label with the location, date and collecting number, and the specimen matches the description in the protologue. The isolectotype at BM has the label "1074/ Mt Wellington" in Gunn's handwriting. It comprises two pressed and mounted branchlets bearing adult leaves, buds and flowers.

Acknowledgments

I am grateful to the Directors of the National Herbarium of Victoria (MEL) and the National Herbarium of New South Wales (NSW), for allowing my access to their eucalypt collections, and for assistance during my visits; Jeremy Bruhl (Australian Botanical Liaison Officer at K, 2008-09) for sending images of eucalypt types or potential types; Brendan Lepschi (CANB) for sending on loan type photographs held at that herbarium. I acknowledge the Board of Trustees, Royal Botanic Gardens, Kew, and the Natural History Museum London (BM) for allowing specimen images to be supplied to me. My sincere thanks to Dr Roberta Vallariello (NAP) and Anna Millozza (RO) for photographing the specimens and labels of *E. elata* types held at their institutions. Gillian Perry cheerfully answered my many nomenclatural queries. Thanks to Alex Buchanan (HO) for his willing assistance with type material of *E. perriniana*, Val Stajsic for supplying information about specimens held at MEL, and to Wayne Gebert and Catherine Gallagher for sending images of some specimens held at MEL.

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Mentha atrolilacina (Lamiaceae), a new species from South Australia

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Abstract

The new species ***Mentha atrolilacina*** B.J.Conn and D.J.Duval (Lamiaceae) from south-eastern South Australia is here described. This species is morphologically similar to *M. diemenica* Sprengel, but can be distinguished by its flowers with a dark lilac corolla (cf. *M. diemenica* often purple to pale purple); corolla short, 3–3.5 mm long (cf. *M. diemenica* 4–7 mm long); anthers included (cf. *M. diemenica* ± distinctly exserted); petioles short, 0.8–1.5 mm long (cf. *M. diemenica* c. 3 mm long).

Introduction

The genus *Mentha* L. (Lamiaceae) consists of mostly perennial herbs and subshrubs in the tribe Mentheae (Harley in Harley et al. 2004). The genus comprises about 20 species in damp, open habitats, especially in the Mediterranean and Australasian regions (Harley in Harley et al. 2004). Prior to the discovery of *M. atrolilacina*, four species were recognised as naturally occurring in Australia, with an additional six species introduced and regarded as naturalised (Conn 1992, 1999).

Mentha atrolilacina B.J.Conn and D.J.Duval ***sp. nov.***

a M. diemenica R.Br. corollis brevioribus (3–3.5 mm longis) atrolilacinis, antheris inclusis differt.

Holotype: South Australia: South-eastern: Honans Scrub Native Forest Reserve, 12 Dec 2007, *D.J. Duval 1017* (AD220419; iso.: NSW860729).

Etymology: from Latin *atrolilacinus*, dark lilac, referring to the dark lilac coloration of the corolla lobes.

Small herb up to c. 55 cm high; stem and branches moderately hairy, hairs simple, curled, ± antrorse (at least distally), 0.07–0.1 mm long, with scattered longer hairs 0.17–0.24 mm long. Leaves aromatic when crushed; petiole 0.8–1.5 mm long, slender, shortly hairy (hairs 0.05–0.07 mm long); lamina membranous, ovate to broadly ovate,

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6–11 mm long, 5–10 mm wide (length to width ratio 1–1.6); minutely hairy, with scattered long, multicellular hairs, especially on veins, moderately glandular (glands hemispherical); base shortly cordate; margin entire; apex rounded. Inflorescences consisting of 3- or 4-flowered simple cymes in distal leaf axils, leaves subtending inflorescence reduced (petiole 0.6–0.7 mm long; lamina ovate, 1.2–2.8 mm long, 0.4–1 mm wide, hairy and glandular as for mature leaves, base cuneate, margin entire, apex obtuse). Podium 0.7–1 mm long; prophylls linear (widest near middle) c. 2 mm long, 0.1–0.2 mm wide, surface hairy, with hairs simple, spreading to slightly retrorse, base long-attenuate, apex acuminate. Calyx 3.3–3.5 mm long, outer surface hairy, hairs white, 0.07–0.1 mm long, spreading to slightly retrorse; tube c. 2.5 mm long, 12-ribbed (especially when dried), mid-green to maroon, inner surface glabrous; lobes triangular, 0.8–1 mm long, 0.8–0.9 mm wide, with maroon tinge, margin and inner distal surface with long white hairs (0.4–0.5 mm long), apex subacute. Corolla dark lilac, 3–3.5 mm long; tube c. 2 mm long, distinctly paler than lobes, outer surface glabrous or with a few scattered hairs, inner surface glabrous; lobes ± equal, ovate, basally abruptly narrowed and straight-sided, outer surface sparsely hairy, glabrous near margin, inner surface glabrous, with margin entire and slightly undulate, abaxial lobe slightly angular-ovate distally, 1.5–1.8 mm long, c. 1.2 mm wide apex rounded, lateral lobes 1–1.4 mm long, 0.8–0.9 mm wide, apex rounded; adaxial lobe 0.8 mm long, 1-1.2 mm wide, 2-lobed, sinus c. 0.3 mm long. Stamens included to slightly exserted; filaments up to c. 0.1 mm long, pale lilac, glabrous; anthers 0.4–0.5 mm long, blue-mauve to pale brown. Disk c. 0.1 mm long; ovary c. 0.5 mm long, green, distal lobes up to c. 0.1 mm long; style 1.5–1.8 mm long, distally curved towards abaxial corolla lobe, dark lilac to almost white (basally); stigma c. 0.3 mm long, lobes 2, linear. Mericarps not known. Figs 1 & 2.

Distribution: this taxon is only known from the Honans Native Forest Reserve, approximately 16 km north-west of Mount Gambier, in the South-eastern region of South Australia.

Ecology: this species is scattered throughout *Eucalyptus ovata*-dominated woodland with an understorey of *Poa labillardierei*, *Mentha diemenica*, *Arthropodium milleflorum* and *Eryngium vesiculosum*. The reserve, previously known as Honans Scrub (ForestrySA 2005), contains 1,030 hectares of native vegetation consisting of *Eucalyptus baxteri*, *E. obliqua*, *E. ovata*, *E. viminalis* subsp. *cygnetensis* and *E. willisii* subsp. *falciformis* (ForestrySA 2005). Additional populations of this species have, as yet, not been located. However, it is thought that this species is likely to occur in nearby reserves and extend to western Victoria.

Conservation status: unknown.

Notes: *Mentha atrolilacina* is morphologically similar to the species of the *Mentha satureioides* complex, namely *M. satureioides* R.Br. and *M. diemenica* Sprengel (Conn 1992, 1999), and to *M. pulegium* L. (Toelken 1986). All four species have hairs on the margin of the calyx lobes. The inner surface of the throat of the calyx tube is hairy in *M. pulegium*, whereas the entire inner surface of the calyx tube is glabrous in the other species. The stamens are included in *M. atrolilacina*, but are exserted in the other species. The broader cordate leaves of *M. atrolilacina* are readily distinguishable from those of *M. diemenica* (Fig. 3).

The corolla lobes become ± strongly recurved when the flower is in the female phase (anthers ± dehisced) and the stigmatic lobes become strongly recurved after fertilisation.

Fig. 1. Habit photograph of *Mentha diemenica* Spreng. (foreground) and *Mentha atrolilacina* B.J.Conn & D.J.Duval (background), illustrating corolla colour (the former species has a much paler corolla than *M. atrolilacina*), size and shape differences.

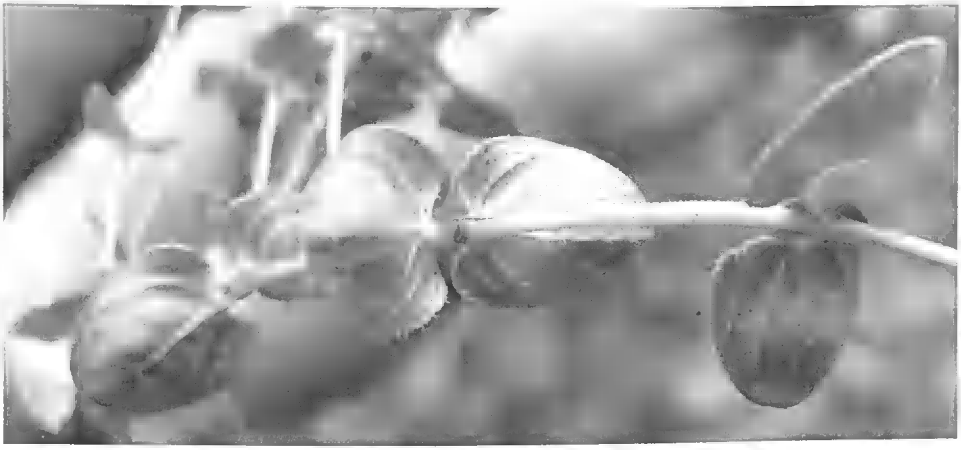

Fig. 2. Photograph of abaxial surface of leaves of *Mentha atrolilacina* illustrating ovate to broadly ovate lamina, with scattered long, multicellular hairs on veins and margin, hemispherical glands hemispherical, and shortly cordate base.

Fig. 3. Photograph of abaxial surface of leaves of *Mentha diemenica* illustrating ovate lamina, hemispherical glands, and rounded base.

Other specimens examined: South Australia: South-eastern: Honans Native Forest Reserve, 7 Dec 2006, *D.J. Duval 724* (AD); 21 Nov 2007, *D.J. Duval 974* (AD); 12 Dec 2007, *D.J. Duval 1017* (AD); 10 Jan 2007, *T.S. Te 155* (AD, MEL).

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The mossflora of Camiguin Island, Philippines and their floristic relations to some adjacent islands in the archipelago

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Abstract

The moss flora of Camiguin Island, based on a 2007 expedition conducted by the author, totaled 129 species in 66 genera and 29 families. This represents 17.36% of the 743 moss species and 26.83% of the 246 genera of mosses reported for the Philippines (Linis & Tan 2008). Of these, one taxon, *Aerobryopsis cochlearifolia* Dix., is reported for the first time in the archipelago. Floristically, Camiguin moss flora is identified more with Mindoro and Luzon within the Philippine archipelago. Likewise, the presence of moss taxa such as *Glossadelphus hermaphroditus* Fleisch. and *Orthomnion javense* (Fleisch.) T. Kop. highlights the role of Mindanao in enriching the moss flora of Camiguin Island. Finally, the importance of remaining forests on the island as a proposed protected area is discussed.

Introduction

Camiguin (Fig. 1) is a small and compact volcanic island province about 54 km southeast of Bohol Island and 10 km north of Misamis Oriental province in the island of Mindanao. With a land area measuring 291.87 sq. km, it lies in the waters of Bohol Sea with geographic coordinates of 124°35' to 124°5' east longitude and 9°5' to 9°20' north latitude (DENR 1998).

The island is part of the northern extreme of Camiguin-Balatocan Range, a volcanic system formed by constructive Quaternary volcanism in Mindanao Island. Despite this geologic connection, however, no historic land link existed between these two islands (Abad 1949). Camiguin has several volcanoes with Mt. Timpoong (1,525 masl) and Mt. Hibok-hibok (1,086 masl) as two of its highest peaks. The latter is classified as an active volcano and is considered a high risk area (PHILVOCS 1990).

Study Areas and Methods

On two trips in May 2007, I documented Camiguin's diversity of mosses. During the first expedition, I joined a team of biodiversity experts from Mindanao State University-Iligan Institute of Technology (MSU-IIT) between 19th and 22nd May 2007

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and surveyed Mt. Timpoong with particular emphasis on the northern slope of the mountain. Afterwards, I returned to the island to survey Mt. Hibok-hibok between 28th and 31th May 2007, concentrating on its north-eastern slope. During these two expeditions, pertinent information about the species habitat, substrates, altitude and other relevant data were recorded. Preliminary identifications, at least to generic level, were done in the field. Final identification was done in the Philippine National Herbarium (PNH), subsequently.

I used Kroeber's % of similarity formula to compare and analyze the floristic affinity of mosses found in Camiguin Island and the first four largest islands within the Philippines: Luzon, Mindoro, Palawan and Mindanao (van Balgooy 1971). Other islands in the archipelago were excluded from this analysis as the bryological information available is inadequate.

Altogether, about 350 specimens of mosses were collected. The voucher specimens of these collections were deposited at PNH with some duplicate specimens sent to the herbarium of MSU-IIT, Iligan City, Lanao del Norte province in Mindanao.

Results and Discussion

Moss diversity: only a few scattered publications mention the mosses of Camiguin Island. Bartram (1939) cited only 20 species (Table 1) while Tan & Iwatsuki (1991) listed 66 taxa when they published their Philippine moss checklist more than fifty years later. Based on this study I accepted 129 species in 66 genera of mosses for Camiguin Island representing 17.36% of the 743 moss species and 26.83% of the total 246 moss genera reported for the Philippines (Linis & Tan 2007).

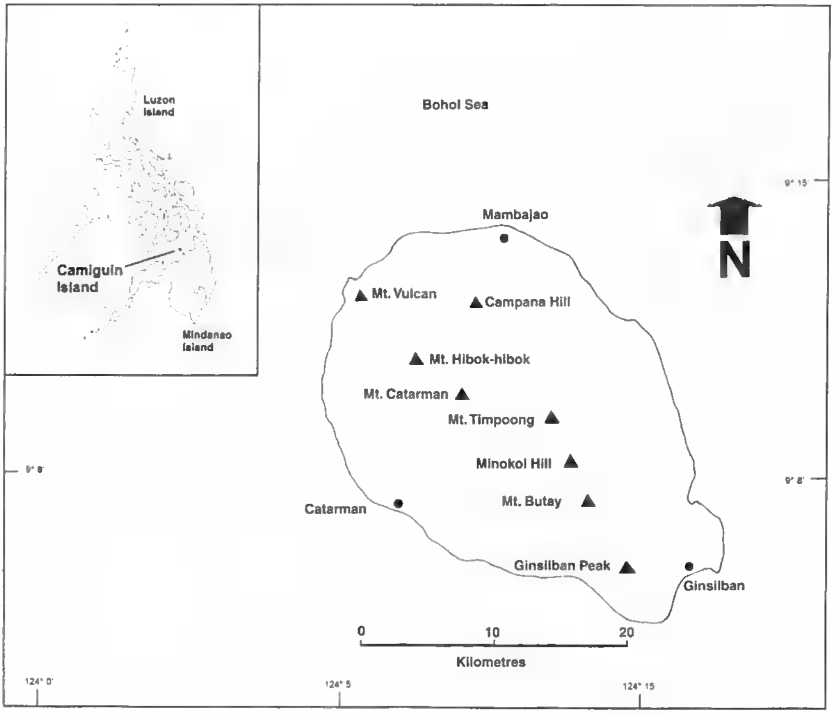

Fig .1. Map of Camiguin Island, Philippines.

Table 1. Comparison of the moss flora of Camiguin Island as reported in this paper with that of Bartram (1939) and Tan & Iwatsuki (1991).

Families	2007 Expedition		Tan & Iwatsuki (1991)		Bartram (1939)	
	Genera	Species	Genera	Species	Genera	Species
1. Polytrichaceae	1	3	1	1	-	-
2. Diphysciaceae	1	1	-	-	-	-
3. Funariaceae	1	1	1	1	-	-
4. Fissidentaceae	1	5	1	3	-	-
5. Ditrichaceae	1	1	-	-	-	-
6. Bruchiaceae	1	1	-	-	-	-
7. Dicranaceae	4	7	2	3	1	1
8. Leucobryaceae	4	11	2	4	-	-
9. Calymperaceae	2	7	2	10	-	-
10. Pottiaceae	2	2	2	2	-	-
11. Orthotrichaceae	1	4	1	2	1	2
12. Bartramiaceae	1	2	1	1	1	1
13. Bryaceae	2	4	2	3	1	1
14. Mniaceae	1	2	-	-	-	-
15. Rhizogoniaceae	1	1	1	1	1	1
16. Spiridentaceae	1	1	1	1	1	1
17. Hypnodendraceae	1	3	1	1	-	-
18. Racopilaceae	1	2	1	1	1	1
19. Ptychomniaceae	1	2	1	1	-	-
20. Hypopterygiaceae	2	4	1	1	-	-
21. Daltoniaceae	2	6	-	-	-	-
22. Pilotrichaceae	2	2	2	2	1	1
23. Thuidiaceae	3	7	2	3	1	1
24. Meteoriaceae	4	5	3	3	1	1
25. Hypnaceae	6	14	4	7	-	-
26. Entodontaceae	2	2	2	2	-	-
27. Sematophyllaceae	10	20	6	9	5	7
28. Pterobryaceae	4	6	1	1	-	-
29. Neckeraceae	3	3	3	3	2	2
Total	66	129	44	66	17	20

Worth mentioning among these collections are the 65 new records for the island (Appendix 1, marked with asterisk). Eight taxa are extensions of range within the Philippines: *Campylopodium medium*; *Clastrobryum caudatum*; *Cyathophorum hookerianum*; *Diphyscium rupestre*; *Distichophyllum osterwaldii*; *Glossadelphus hermaphroditus*; *Pterobryopsis gedehensis* and, *Syrrhopodon prolifer*.

From the new collections, one species, *Aerobryopsis cochlearifolia* Dix., proves to be a new record for the Philippine moss flora (Fig. 2). Previously this species was found only in Indochina and was known only from two collections in Laos and Thailand (Noguchi 1976).

In general, the moss diversity of Camiguin Island is highest in mid-elevation forests from 600 to 1500 masl. At these elevations, mosses were observed to be most abundant in wetter forests found on the east-facing slopes of the volcanic peaks and in riverine forests. Such forests support hygrophytic moss genera like *Orthomnion*, *Cyathophorum*, *Calyptrochaeta*, *Distichophyllum*, *Hypnodendron* and *Garovaglia*. Below these elevations, however, the number and diversity of mosses decreases due to the prevalence of grasslands and cultivated areas. In these semi-dry and anthropogenic habitats, moss genera such as *Barbula*, *Bryum*, *Hyophila*, *Garckea*, *Campylopodium* and *Calymperes* thrive.

Floristic affinity: the Camiguin moss flora is most similar to that of Mindoro followed by Luzon (Table 2). Many of the taxa not shared by Mindoro and Camiguin are contributed by those taxa present in Mindoro and neighboring Luzon but absent from the rest of the islands within the Philippine archipelago. Other taxa not shared by Mindoro and Camiguin include those known only from Mindoro such as *Rhacocarpus alpinus* (Wright.) Par., *Dicranoloma daymannianum* Bartr. and *Distichophyllum noguchianum* Tan (Mindoro's sole endemic). The remaining taxa are likely to be undercollected and may well occur elsewhere in the Philippines.

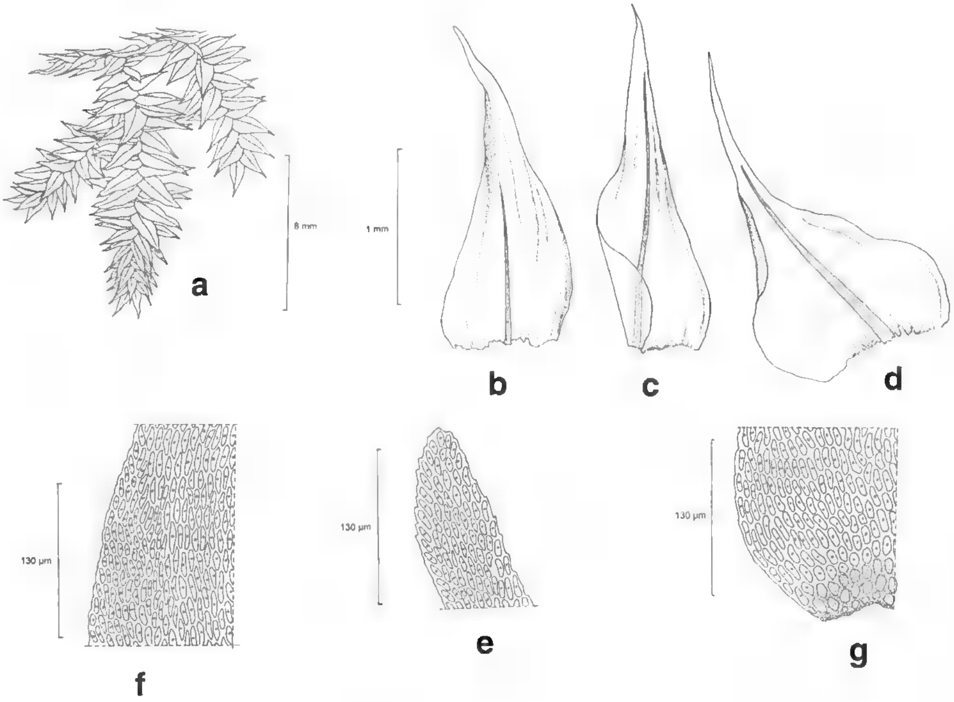

Fig. 2. ***Aerobryopsis cochlearifolia*** **Dix.** **a,** part of the plant; **b, c,** branch-leaves; **d,** stem leaf; **e,** apex of branch leaf; **f,** cells from middle of branch leaf; **g,** cells from base of branch leaf.

Table 2. Kroeber's percentage of taxic similarity (%K) between the moss floras of Camiguin, Luzon, Mindoro, Palawan and Mindanao. The numbers are derived from the current work plus previous reports by Bartram (1939), Linis (2004, 2007), Linis & Tan (2005), Tan (1996), Tan & Iwatsuki (1991), Tan & Mandia (2001), Tan et al. (2000).

	Luzon **614 species**		***Mindoro*** **279 species**		***Palawan*** **221 species**		***Mindanao*** **336 species**	
Camiguin	shared	Unshared	Shared	unshared	shared	unshared	shared	unshared
129 species	121	493	111	168	67	134	105	231
%K	56.75		62.92		53.40		56.32	

* Kroeber's % of similarity = C (A + B)/ 2AB x 100

A = the number of taxa present in the first area under comparison
B = the number of taxa present in the second area under comparison
C = the number of common taxa in both A & B areas.

Most of the taxa not common to Luzon and Camiguin are those species restricted to higher altitudes, over 1800 masl, mostly in the Northern Cordillera of Luzon (*Atrichum crispulum* Schimp. ex Besch., *Chrysocladium flammeum* (Mitt.) M.Fleisch., *Fabronia curvirostris* Dozy & Molk., *Heterophyllium affine* (Hook.) M.Fleisch., *Leptohymenium tenue* (Hook.) Schwägr., *Neckera crenulata* Harv. and *Timmiella anomala* (Bruch & Schimp.) Limpr.) or island endemics (*Calyptothecium squarrosulum* Nog. & B.C. Tan, *Chaetomitrium perarmatum* Broth., *Jaegerina williamsii* E.B. Bartram and *Stereophyllum linisii* Enroth & B.C. Tan). Remaining unshared taxa are likely to be an artifact of under-collecting. It is my opinion that long-distance dispersal is the most likely explanation for this strong relationship between Luzon and Camiguin, as many mosses are dispersed by wind-borne spores. Another possibility is that moss taxa have 'island hopped' along the intervening islands, finally reaching Camiguin. In view of the large number of shared taxa involved between Luzon and Camiguin it is most likely that many of these taxa may eventually be found in the intervening islands.

Taxa not common to Camiguin and Mindanao islands include South Malesian and Australasian genera such as *Bryobrothera*, *Dawsonia*, *Ectropotheciopsis*, *Leskeodon* and *Meiotheciella* that appear to have reached only Mindanao in the Philippines. At least two species of mosses: *Glossadelphus hermaphroditus* Fleisch. and *Orthomnion javense* (Fleisch.) T.Kop., formerly known in the Philippines only from Mindanao, were found in Camiguin during the first 2007 expedition. This could indicate that dispersal from Mindanao to Camiguin is occurring, but it is more probable, given the islands are separated by c. 10 km, that floristic differences between Camiguin and Mindanao are mainly due to under-collection of moss taxa in northern Mindanao (Tan et al. 2000).

Finally, Palawan Island which supports semi-dry and seasonally deciduous type of rain forests has a moss flora least similar to that of Camiguin. This is not surprising as Palawan supports a handful of xeric or drought-tolerant moss taxa not found in the rest of the Philippine archipelago. Other Palawan taxa, such as *Clastrobryum asperrimum* (Dix.) Tan and *Horikawaea tjibodensis* (M.Fleisch.) M.C.Ji & Enroth, represent South and West Malesian taxa that have apparently failed to reach other islands of the Philippines. Undercollection may also have a role to play in the distribution patterns reported here.

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Appendix. Updated checklist of Camiguin mosses and their intra-Philippine distribution.

* New records added from the 2007 expedition.

1. *Acanthorrhynchium papillatum* (Harv.) M.Fleisch. - widespread
Mt. Hibok-hibok, 600m elev., on tree roots and lower tree trunk; Residual lowland forest, May 31, 2007, V.C. Linis 2779-07.

2. *Acroporium diminutum* (Brid.) M.Fleisch. – widespread
Mt. Timpoong, 1350 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2563-07.

3. **A. hermaphroditum* (Müll.Hal.) M.Fleisch. – Luzon and Mindanao
Mt. Timpoong, 1350 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2554-07.

4. **A. ramicola* (Hampe) Broth. – Mindanao
Mt. Timpoong, 1530 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2578-07.

5. **A. secundum* (Reinw. & Hornsch.) M.Fleisch. – Luzon, Mindoro, Palawan & Western Mindanao
Mt. Timpoong, 1530 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2593-07.

6. **A. sigmatodontium* (Müll.Hal.) M.Fleisch. – Luzon, Mindoro and Panay
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional lowland forest, May 19, 2007, V.C. Linis 2498-07. **Mt. Hibok-hibok**, 900 m elev., on tree trunk; Transitional lowland forest, May 30, 2007, V.C. Linis 2691-07.

7. *A. strepsiphyllum* (Mont.) B.C.Tan var. *strepsiphyllum* – Luzon and Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional lowland forest, May 19, 2007, V.C. Linis 2493-07. **Mt. Timpoong**, 1350 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2560-07. , **Mt. Hibok-hibok**, 900 m elev., on tree trunk; Transitional lowland forest, May 30, 2007, V.C. Linis 2686-07.

8. **Aerobryopsis cochlearifolia* Dix. – new Philippine record
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree trunk near creek; Transitional lowlandforest, May 20, 2007, V.C. Linis 2622-07.

9. *A. wallichii* (Brid.) M.Fleisch. – widespread
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 680 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2442-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 680 m elev., on lower tree branches; Lowland forest, May 19, 2007, V.C. Linis 2444-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 850 m elev., on tree branch; Transitional lowland forest, May 19, 2007, V.C. Linis 2474-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree branch; Transitional lowland forest, May 19, 2007, V.C. Linis 2497-07. **Mt. Timpoong**, 1350 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2568-07. **Mt. Hibok-hibok**, 320 m elev., on tree trunk; Residual lowland forest, May 29, 2007, V.C. Linis 2635-07. **Mt. Hibok-hibok**, 700 m elev., on tree branch; Transitional lowland forest, May 29, 2007, V.C. Linis 2667-07. **Mt. Hibok-hibok**, 900 m elev., on tree branch; Transitional lowland forest, May 30, 2007, V.C. Linis 2690-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Residual lowland forest, May 31, 2007, V.C. Linis 2758-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Residual lowland forest, May 31, 2007, V.C. Linis 2760-07.

10. **Aerobryum speciosum* Dozy & Molk. – Luzon and Mindanao
Mt. Timpoong, 1530 m elev., on tree branches; Montane forest, May 21, 2007, V.C. Linis 2592-07.

11. *Barbula indica* (Hook.) Spreng. – widespread
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on soil; Agricultural land, May 22, 2007, V.C. Linis 2609-07. **Mt. Hibok-hibok**, 850 m elev., on soil; Transitional lowland forest, May 31, 2007, V.C. Linis 2733-07.

12. *Brachymenium nepalense* Hook. – widespread
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 800 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2465-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional lowland forest, May 19, 2007, V.C. Linis 2490-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Secondary lowland forest, May 29, 2007, V.C. Linis 2658-07. **Mt. Hibok-hibok**, 860 m elev., on tree trunk; Transitional lowland forest, May 30, 2007, V.C. Linis 2683-07.

13. **Bryum clavatum* (Schimp.) Müll.Hal. – Luzon and Mindoro
Brgy. Tagdo, Mambajao (footslope of Mt. Hibok-hibok), 180 m elev., on boulder near hot spring; Human Settlement area, May 21, 2007, V.C. Linis 2613-07. **Mt. Hibokhibok**, 850 m elev., on boulder; Transitional lowland forest, May 31, 2007, V.C. 2737-07.

14. *B. coronatum* Schwägr. – widespread
Mambajao Town proper, 10 m elev., on concrete wall; Agricultural land, May 19, 2007, V.C. Linis 2434-07. , **Mt. Hibok-hibok**, 180 m elev., on concrete wall; Agricultural land, May 29, 2007, V.C. Linis 2627-07., **Mt. Hibok-hibok**, 800 m elev., on stone wall; Transitional lowland forest, May 31, 2007, V.C. Linis 2750-07.

15. *Callicostella papillata* (Mont.) Mitt. – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1020 m elev., on wet rocks; Transitional lowland forest, May 20, 2007, V.C. Linis 2526-07. **Mt. Hibok-hibok**, 950 m elev., on rotten tree roots; Transitional lowland forest, May 30, 2007, V.C. Linis 2712-07. **Mt. Hibok-hibok**, 1000 m elev., on wet rocks; Transitional lowland forest, May 30, 2007, V.C. Linis 2719-07.

16. *Calymperes graeffeanum* Müll.Hal. – widespread
Mt. Hibok-hibok, 180 m elev., on dead tree trunk; Agricultural land, May 29, 2007, V.C. Linis 2625-07.

17. **C. strictifolium* (Mitt.) G.Roth. – Luzon and Mindanao
Brgy. Pandan, Mambajao, 680 m elev., on dead tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2443-07. **Mt. Hibok-hibok**, 320 m elev., on dead tree trunk; Residual Lowland forest, May 29, 2007, V.C. Linis 2636-07. **Mt. Hibok-hibok**, 650 m elev., on dead tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2759-07.

18. *C. tahitense* (Sull.) Mitt. – widespread
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 740 m elev., on lower tree trunk Lowland forest, May 19, 2007, V.C. Linis 2459-07. **Mt. Hibok-hibok**, 650 m elev., on lower tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2652-07. **Mt. Hibok-hibok**, 600 m elev., on lower tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2775-07.

19. *C. tenerum* Müll.Hal. – widespread
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on dead tree trunk; Agricultural land, May 19, 2007, V.C. Linis 2432-07. **Brgy. Tagdo, Mambajao** (foot of Mt. Hibok-hibok), 180 m elev., on tree trunk near hot spring; Human Settlement area, May 21, 2007, V.C. Linis 2614-07. **Mt. Hibok-hibok**, 850 m elev., on tree trunk; Transitional Lowland forest, May 31, 2007, V.C. Linis 2738-07. **Mt. Hibok-hibok**, 800 m elev., on dead tree trunk; Transitional Lowland forest, May 31, 2007, V.C. Linis 2748-07.

20. **Calyptrochaeta fláccida* (Broth.) Z.Iwats., B.C.Tan & Touw - Luzon
Mt. Timpoong, 1250 m elev., on stem of small tree; Montane forest, May 21, 2007, V.C. Linis 2540-07. **Mt. Timpoong**, 1350 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2559-07. **Mt. Timpoong**, 1400 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2574-07. **Mt. Timpoong**, 1530 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2577-07.

21. **C. remotifolia* (Müll.Hal.) Z.Iwats., B.C Tan & Touw – Luzon and Mindanao
Mt. Timpoong, 1250 m elev., on wet rocks; Montane forest, May 21, 2007, V.C. Linis 2537-07. **Danao, Mambajao**, 1000 m elev., on wet rocks; Transitional Lowland forest, May 22, 2007, V.C. Linis 2601-07. **Mt. Hibok-hibok**, 1000 m elev., on wet rocks; Transitional Lowland forest, May 30, 2007, V.C. Linis 2725-07.

22. **Campylopodium medium* (Duby) Giese & J.-P.Frahm – Luzon and Mindoro
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on eroded soil bank alongside road; Agricultural land, May 19, 2007, V.C. Linis 2426-07. **Campana, Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 520 m elev., on eroded soil bank alongside road; Agricultural land, May 19, 2007, V.C. Linis 2436-07. **Mt. Hibok-hibok**, 180 m elev., on eroded soil bank alongside road; Agricultural land, May 29, 2007, V.C. Linis 2629-07. **Mt. Hibok-hibok**, 800 m elev., on eroded soil bank alongside trail; Transitional Lowland forest, May 31, 2007, V.C. Linis 2752-07.

23. **Campylopus comosus* (Schwägr.) Bosch & Sande Lac. – Luzon and Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 850 m elev., on trunk ofpalm (*Caryota* sp.) tree; Transitional Lowland forest, May 19, 2007, V.C. Linis 2475-07.

24. *C. umbellatus* (Schwägr. & Gaudich. ex Arn.) Paris – widespread
Mt. Hibok-hibok, 700 m elev., on moist soil bank; Transitional Lowland forest, May 29, 2007, V.C. Linis 2668-07.

25. *Claopodium prionophyllum* (Müll.Hal.) Broth. – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on wet rocks along creek; Transitional Lowland forest, May 20, 2007, V.C. Linis 2512-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1020 m elev., on wet rocks; Transitional Lowland forest, May 20, 2007, V.C. Linis 2531-07. **Mt. Hibok-hibok**, 950 m elev., on wet rocks; Transitional Lowland forest, May 30, 2007, V.C. Linis 2705-07.

26. **Clastobryum caudatum* M.Fleisch. – Luzon and Mindoro
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on dead tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2499-07. **Mt. Hibok-hibok**, 900 m elev., on dead tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2692-07.

27. **Cryptopapillaria fuscescens* (Hook.) M.Menzel – Luzon and Mindanao
Mt. Timpoong, 1400 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2571-07.

28. **Cyathophorum hookerianum* (Griff.) Mitt. – Luzon
Mt. Timpoong, 1350 m elev., on stem of small tree; Montane forest, May 21, 2007, V.C. Linis 2553-07.

29. **C. parvifolium* Bosch & Sande Lac. – Luzon and Mindanao
Mt. Timpoong, 1250 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2535-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1020 m elev., on tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2623-07. **Mt. Hibok-hibok**, 800 m elev., on tree trunk; Transitional Lowland forest, May 31, 2007, V.C. Linis 2746-07.

30. **C. spinosum* (Müll.Hal.) M.Fleisch. – Luzon and some islands in the Visayas
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2509-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1020 m elev., on wet rocks along trail; Transitional Lowland forest, May 20, 2007, V.C. Linis 2522-07. **Mt. Hibok-hibok**, 900 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2702-07. **Mt. Hibok-hibok**, 1000 m elev., on wet rocks along trail; Transitional Lowland forest, May 30, 2007, V.C. Linis 2715-07.

31. *Cyclodictyon blumeanum* (Müll.Hal.) Kuntze – widespread
Mt. Timpoong, 1530 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2579-07.

32. *Dicranoloma assimile* (Hampe) Paris – Luzon and Mindanao
Mt. Hibok-hibok, 700 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2671-07.

33. *D. blumii* (Nees) Ren. – widespread
Mt. Timpoong, 1530 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2589-07.

34. *D. braunii* (Müll.Hal.) Paris – Luzon, Palawan, some islands in the Visayas and Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2478-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2508-07. **Mt. Hibok-hibok**, 900 m elev., on wet rocks along trail; Transitional Lowland forest, May 30, 2007, V.C. Linis 2700-07. **Mt. Hibok-hibok**, 900 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2701-07.

35. **D. reflexum* (Müll.Hal.) Renauld. – Luzon and some islands in the Visayas
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 850 m elev., on tree branch; Transitional Lowland forest, May 19, 2007, V.C. Linis 2471-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2502-07. **Mt. Timpoong**, 1350 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2552-07. **Mt. Hibok-hibok**, 700 m elev., on tree branch; Transitional Lowland forest, May 29, 2007, V.C. Linis 2664-07. **Mt. Hibok-hibok**, 900 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2695-07.

36. **Diphyscium rupestre* Dozy & Molk. – Luzon and some islands in the Visayas
Danao, Mambajao (midslope of Mt. Timpoong), 1020 m elev., on wet rocks along trail;

Transitional Lowland forest, May 20, 2007, V.C. Linis 2532-07.

37. **Distichophyllum cuspidatum* (Dozy & Molk.) Dozy & Molk. – Luzon and Mindanao
Mt. Timpoong, 1530 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2580-07.

38. **D. mittenii* Bosch & Sande Lac. – Luzon and Mindanao
Mt. Timpoong, 1530 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2576-07.

39. **D. nigricaule* Mitt. ex Bosch & Sande Lac. – Luzon, Mindoro, Palawan and Western Mindanao
Mt. Timpoong, 1350 m elev., on wet rocks; Montane forest, May 21, 2007, V.C. Linis 2548-07.

40. **D. osterwaldii* M.Fleisch. – Luzon and some islands in the Visayas
Mt. Timpoong, 1250 m elev., on wet rocks; Montane forest, May 21, 2007, V.C. Linis 2536-07. **Mt. Timpoong**, 1530 m elev., on base of tree trunk; Montane forest, May 21, 2007, V.C. Linis 2597-07.

41. *Ectropotheciella distichophylla* (Hampe ex Dozy & Molk.) M.Fleisch. – widespread
Mt. Hibok-hibok, 650 m elev., on tree trunk; Residual Lowland forest, May 29, 2007, V.C. Linis 2657-07.

42. *Ectropothecium buitenzorgii* (Bel.) Mitt. – widespread
Mt. Hibok-hibok, 900 m elev., on base of decaying tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2689-07.

43. *E. dealbatum* (Reinw. & Hornsch.) A.Jaeger – widespread
Mt. Hibok-hibok, 320 m elev., on moist soil beside trail; Residual Lowland forest, May 29, 2007, V.C. Linis 2634-07.

44. **E. falciforme* (Dozy & Molk.) A.Jaeger – Luzon and Mindanao
Mt. Timpoong, 1350 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2556-07. **Mt. Timpoong**, 1350 m elev., on stem of small tree; Montane forest, May 21, 2007, V.C. Linis 2557-07.

45. *E. monumentorum* (Duby) A.Jaeger – widespread.
Mt. Hibok-hibok, 320 m elev., on rocks; Residual Lowland forest, May 29, 2007, V.C. Linis 2637-07.

46. **E. perminutum* Broth. ex E.B.Bartram – Luzon and Mindoro
Danao, Mambajao (midslope of Mt. Timpoong), 1020 m elev., on wet rocks; Transitional Lowland forest, May 20, 2007, V.C. Linis 2525-07. **Mt. Hibok-hibok**, 1000 m elev., on wet rocks; Transitional Lowland forest, May 30, 2007, V.C. Linis 2718-07.

47. *Erythrodontium julaceum* (Hook ex Schwägr.) Paris – widespread
Mt. Hibok-hibok, 510 m elev., on tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2651-07.

48. **Exostratum blumii* (Nees ex Hampe) L.T.Ellis – Luzon and Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on base of tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2495-07. **Mt. Hibok-hibok**, 900 m elev., on base of tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2688-07.

49. *Fissidens crenulatus* Mitt. var. *elmeri* (Broth.) Z.Iwats. & Tad.Suzuki – widespread
Mt. Timpoong, 1250 m elev., on trunk of tree ferns; Montane forest, May 21, 2007, V.C. Linis 2539-07.

50. *F. crispulus* Brid. – widespread
Brgy. Tagdo, Mambajao (footslope of Mt. Hibok-hibok), 180 m elev., on soil adjacent to hot srping; Human Settlement area, May 21, 2007, V.C. Linis 2616-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on wet rocks near creek; Transitional Lowland forest, May 21, 2007, V.C. Linis 2620-07. **Mt. Hibok-hibok**, 850 m elev., on soil; Transitional Lowland forest, May 31, 2007, V.C. Linis 2740-07. **Mt. Hibok-hibok**, 850 m elev., on wet rocks; Transitional Lowland forest, May 31, 2007, V.C. Linis 2743-07.

51. *F. nobilis* Griff. – widespread
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 740 m elev., on soil bank alongside trail; Lowland forest, May 19, 2007, V.C. Linis 2460-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on wet rocks near creek; Transitional Lowland forest, May 20, 2007, V.C.

Linis 2515-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on wet rocks along trail; Transitional Lowland forest, May 22, 2007, V.C. Linis 2600-07. **Mt. Hibok-hibok**, 650 m elev., on soil bank alongside trail; Secondary Lowland forest, May 29, 2007, V.C. Linis 2653-07. **Mt. Hibok-hibok**, 600 m elev., on soil bank alongside trail; Residual Lowland forest, May 31, 2007, V.C. Linis 2777-07.

52. **F. oblongifolius* Hook.f. & Wilson – Mindoro and some islands in the Visayas
Mt. Hibok-hibok, 950 m elev., on wet rocks; Transitional Lowland forest, May 30, 2007, V.C. Linis 2708-07.

53. **F. punctulatus* Sande Lac. – Luzon
Mambajao Town Proper, 10 m elev., on rocks; Human Settlement area, May 21, 2007, V.C. Linis 2611-07. **Mt. Hibok-hibok**, 850 m elev., on rocks; Transitional Lowland forest, May 31, 2007, V.C. Linis 2735-07.

54. *Floribundaria floribunda* (Dozy & Molk.) M.Fleisch. – widespread
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 720 m elev., on lower tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2448-07. **Mt. Timpoong**, 1350 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2558-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 800 m elev., on tree trunk; Lowland forest, May 22, 2007, V.C. Linis 2598-07. **Mt. Hibok-hibok**, 320 m elev., on lower tree trunk; Residual Lowland forest, May 29, 2007, V.C. Linis 2641-07. **Mt. Hibok-hibok**, 650 m elev., on lower tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2764-07.

55. *Funaria hygrometrica* Hedw. – widespread
Mt. Hibok-hibok, 1000 m elev., on burnt soil and charred wood; Transitional Lowland forest, May 30, 2007, V.C. Linis 2724-07.

56. **Garckea comosa* (Dozy & Molk.) Wijk & Margad. – Luzon, Mindoro and Palawan
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on eroded soil bank alongside road; Agricultural land, May 19, 2007, V.C. Linis 2427-07.

57. **Garovaglia angustifolia* Mitt. – Luzon and Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 680 m elev., on tree trunk and branches; Lowland forest, May 19, 2007, V.C. Linis 2447-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 850 m elev., on tree branch; Transitional Lowland forest, May 19, 2007, V.C. Linis 2472-07.**Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree branch; Transitional Lowland forest, May 19, 2007, V.C. Linis 2482-07. **Mt. Timpoong**, 1250 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2533-07. **Mt. Hibok-hibok**, 320 m elev., on tree trunk and branches; Residual Lowland forest, May 29, 2007, V.C. Linis 2460-07. **Mt. Hibok-hibok**, 700 m elev., on tree branch; Transitional Lowland forest, May 29, 2007, V.C. Linis 2665-07. **Mt. Hibok-hibok**, 860 m elev., on tree branch; Transitional Lowland forest, May 30, 2007, V.C. Linis 2675-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk and branches; Residual Lowland forest, May 31, 2007, V.C. Linis 2763-07.

58. *G. elegans* (Dozy & Molk.) Hampe ex Bosch & Sande Lac. – widespread
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 720 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2452-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 740 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2457-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 850 m elev., on tree branch; Transitional Lowland forest, May 19, 2007, V.C. Linis 2476-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2483-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2506-07. **Mt. Timpoong**, 1350 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2544-07. **Mt. Hibok-hibok**, 450 m elev., on tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2645-07. **Mt. Hibok-hibok**, 510 m elev., on tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2650-07. **Mt. Hibok-hibok**, 700 m elev., on tree trunk; Transitional Lowland forest, May 29, 2007, V.C. Linis 2669-07. **Mt. Hibok-hibok**, 860 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2676-07. **Mt. Hibok-hibok**, 900 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2699-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2768-07. **Mt. Hibok-hibok**, 600 m elev., on tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2773-07.

59. **Glossadelphus hermaphroditus* M.Fleisch. – Mindanao
Mt. Timpoong, 1530 m elev., on base of tree trunk; Montane forest, May 21, 2007, V.C. Linis 2585-07.

60. *Himantocladium cyclophyllum* (Müll.Hal.) M.Fleisch. – widespread
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 680 m elev., on tree branch; Lowland forest, May 19, 2007, V.C. Linis 2466-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 800 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2468-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree stem near creek; Transitional Lowland forest, May 20, 2007, V.C. Linis 2511-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk near creek; Transitional Lowland forest, May 20, 2007, V.C. Linis 2518-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1020 m elev., on tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2529-07. **Hibok-hibok**, 320 m elev., on tree branch; Residual Lowland forest, May 29, 2007, V.C. Linis 2639-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2661-07. **Mt. Hibok-hibok**, 950 m elev., on tree stem near creek; Transitional Lowland forest, May 30, 2007, V.C. Linis 2711-07. **Mt. Hibok-hibok**, 950 m elev., on tree trunk near creek; Transitional Lowland forest, May 30, 2007, V.C. Linis 2699-07. **Mt. Hibok-hibok**, 1000 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2722-07. **Mt. Hibok-hibok**, 650 m elev., on tree branch; Residual Lowland forest, May 31, 2007, V.C. Linis 2762-07.

61. *Homaliodendron flabellatum* (Sm.) M.Fleisch. – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2477-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2481-07. **Mt. Timpoong**, 1350 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2547-07. **Mt. Timpoong**, 1400 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2570-07. **Mt. Hibok-hibok**, 700 m elev., on tree trunk; Transitional Lowland forest, May 29, 2007, V.C. Linis 2670-07. **Mt. Hibok-hibok**, 700 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2674-07.

62. *Hyophila involuta* (Hook.) A.Jaeger. – widespread
Mambajao Town Proper, 10 m elev., on concrete wall; Human Settlement area, May 21, 2007, V.C. Linis 2610-07. **Mt. Hibok-hibok**, 850 m elev., on rock wall; Transitional Lowland forest, May 31, 2007, V.C. Linis 2734-07.

63. **Hypnodendron milnei* Mitt. ssp. *korthalsii* (Bosch & Sande Lac. ex Paris) Touw – Luzon, Mindoro, Palawan and Western Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on wet rocks along trail; Transitional Lowland forest, May 19, 2007, V.C. Linis 2485-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on wet rocks along trail; Transitional Lowland forest, May 19, 2007, V.C. Linis 2504-07. **Mt. Hibok-hibok**, 860 m elev., on wet rocks along trail; Transitional Lowland forest, May 30, 2007, V.C. Linis 2678-07. **Mt. Hibok-hibok**, 900 m elev., on wet rocks alongside trail; Transitional Lowland forest, May 30, 2007, V.C. Linis 2697-07.

64. *H. reinwardtii* (Schwägr.) Lindb. ex A.Jaeger & Sauerb. ssp. *caducifolium* (Herzog) Touw – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on base of tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2496-07. **Mt. Timpoong**, 1250 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2534-07. **Mt. Timpoong**, 1400 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2572-07. **Mt. Timpoong**, 1530 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2591-07.

65. **H. vitiense* Mitt. – Luzon and Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1020 m elev., on wet boulders; Transitional Lowland forest, May 20, 2007, V.C. Linis 2532-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 22, 2007, V.C. Linis 2602-07. **Mt. Hibok-hibok**, 950 m elev., on dead tree branch; Transitional Lowland forest, May 30, 2007, V.C. Linis 2713-07. **Mt. Hibok-hibok**, 1000 m elev., on wet boulders; Transitional Lowland forest, May 30, 2007, V.C. Linis 2716-07. **Mt. Hibok-hibok**, 1000 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2726-07.

66. **Isopterygium albescens* (Hook.) A.Jaeger – Luzon and some islands in the Visayas
Mt. Timpoong, 1250 m elev., on stem of small tree; Montane forest, May 21, 2007, V.C. Linis 2538-07. **Mt. Timpoong**, 1530 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2595-07.

67. **I. minutirameum* (Müll.Hal.) A.Jaeger – Luzon, Mindoro and Palawan
Mt. Timpoong, 1350 m elev., on woody vine; Montane forest, May 21, 2007, V.C. Linis 2550-07.

68. **Leucobryum aduncum* Dozy & Molk. – Luzon, Mindoro and Palawan
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on tree trunk alongside road; Agricultural land, May 19, 2007, V.C. Linis 2428-07.

69. **L. chlorophyllosum* Müll.Hal. – Mindoro and some islands in the Visayas
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on base of tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2505-07. **Mt. Hibok-hibok**, 900 m elev., on base of tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2698-07.

70. *L. javense* (Brid.) Mitt. - widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on base of tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2487-07. **Mt. Timpoong**, 1530 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2581-07. **Mt. Hibok-hibok**, 860 m elev., on base of tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2680-07.

71. **L. juniperoideum* (Brid.) Müll.Hal. – Luzon, Mindoro and Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 800 m elev., on tree branch; Grassland, May 19, 2007, V.C. Linis 2464-07.

72. *L. sanctum* (Nees ex Schwägr.) Hampe – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on dead tree branch; Transitional Lowland forest, May 20, 2007, V.C. Linis 2520-07.

73. *L. scalare* Müll.Hal. ex M.Fleisch. – Luzon and some islands in the Visayas
Mt. Timpoong, 1530 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2582-07.

74. **Leucoloma molle* (Müll.Hal.) Mitt. – Luzon and Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2488-07. **Mt. Hibok-hibok**, 860 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2681-07.

75. **Leucophanes angustifolium* Renauld & Cardot – Luzon and Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 720 m elev., on lower tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2453-07. **Mt. Timpoong**, 1250 m elev., on trunk of tree ferns; Montane forest, May 21, 2007, V.C. Linis 2542-07. **Mt. Hibok-hibok**, 450 m elev., on lower tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2646-07. **Mt. Hibok-hibok**, 600 m elev., on lower tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2769-07.

76. *L. candidum* (Schwägr.) Lindb. – widespread
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 850 m elev., on trunk of palm (*Caryota* sp.) tree; Transitional Lowland forest, May 22, 2007, V.C. Linis 2607-07. **Mt. Hibok-hibok**, 850 m elev., on trunk of palm tree; Transitional Lowland forest, May 31, 2007, V.C. Linis 2731-07.

77. **L. glaucum* (Schwägr.) Mitt. – Luzon and Mindanao
Brgy. Tagdo, Mambajao (footslope of Mt. Hibok-hibok), 180 m elev., on base of palm's trunk near to hot spring; Human Settlement area, May 21, 2007, V.C. Linis 2612-07. **Mt. Hibok-hibok**, 850 m elev., on base of palm's trunk; Transitional Lowland forest, May 31, 2007, V.C. Linis 2736-07.

78. **L. octoblepharioides* Brid. – Luzon and Mindanao
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on base of tree trunk; Agricultural land, May 19, 2007, V.C. Linis 2431-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 720 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2455-07. **Mt. Hibok-hibok**, 180 m elev., on base of tree trunk; Agricultural land, May 29, 2007, V.C. Linis 2624-07. **Mt. Hibok-hibok**, 510 m elev., on tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2648-07. **Mt. Hibok-hibok**, 800 m elev., on base of tree trunk; Transitional Lowland forest, May 31, 2007, V.C. Linis 2747-07. **Mt. Hibok-hibok**, 600 m elev., on tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2771-07.

79. *Lopidium struthiopteris* (Brid.) M.Fleisch. – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2484-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2492-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1020 m elev., on tree trunk; Transitional Lowland forest,

May 20, 2007, V.C. Linis 2521-07. **Mt. Hibok-hibok**, 860 m elev., on tree trunk; Transitional Lowland forest, May 31, 2007, V.C. Linis 2677-07. **Mt. Hibok-hibok**, 900 m elev., on tree trunk; Transitional Lowland forest, May 31, 2007, V.C. Linis 2685-07. **Mt. Hibok-hibok**, 950 m elev., on tree trunk; Transitional Lowland forest, May 31, 2007, V.C. Linis 2714-07.

80. **Macromitrium angustifolium* Dozy & Molk. – Luzon and Mindoro
Danao, Mambajao (midslope of Mt. Timpoong), 1020 m elev., on tree branch near creek; Transitional Lowland forest, May 20, 2007, V.C. Linis 2514-07. **Mt. Hibok-hibok**, 950 m elev., on tree branch; Transitional Lowland forest, May 30, 2007, V.C. Linis 2707-07.

81. *M. orthostichum* Nees & Schwägr. – Luzon, Mindoro, Palawan and Western Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 800 m elev., on tree branch; Grassland, May 19, 2007, V.C. Linis 2461-07. **Mt. Hibok-hibok**, 650 m elev., on tree branch; Grassland, May 29, 2007, V.C. Linis 2654-07. **Mt. Hibok-hibok**, 500 m elev., on tree branch; Grassland, May 31, 2007, V.C. Linis 2778-07.

82. *M. salakanum* Müll.Hal. – Luzon, Mindoro, Palawan and Western Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 800 m elev., on tree trunk; Grassland, May 19, 2007, V.C. Linis 2462-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 800 m elev., on tree branches; Grassland, May 19, 2007, V.C. Linis 2463-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree branch; Transitional Lowland forest, May 22, 2007, V.C. Linis 2603-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Grassland, May 29, 2007, V.C. Linis 2655-07. **Mt. Hibok-hibok**, 1000 m elev., on tree branch; Transitional Lowland forest, May 30, 2007, V.C. Linis 2727-07.

83. **M. subtile* Schwägr. ssp. *subuligerum* (Bosch & Sande Lac.) M.Fleisch. – Luzon, Mindoro, Palawan and Western Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 680 m elev., on tree branch; Lowland forest, May 19, 2007, V.C. Linis 2439-07. **Mt. Hibok-hibok**, 180 m elev., on tree branch; Residual Lowland forest, May 29, 2007, V.C. Linis 2632-07. **Mt. Hibok-hibok**, 650 m elev., on tree branch; Residual Lowland forest, May 31, 2007, V.C. Linis 2755-07.

84. **Meiothecium hamatum* (Müll.Hal.) Broth. – Luzon and some islands in the Visayas
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2479-07.

85. *Meteorium polytrichum* Dozy & Molk. – widespread
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 800 m elev., on tree branch; Lowland forest, May 19, 2007, V.C. Linis 2469-07. **Mt. Hibok-hibok**, 700 m elev., on tree branch; Secondary Lowland forest, May 29, 2007, V.C. Linis 2662-07.

86. *Neckeropsis lepineana* (Mont.) M.Fleisch. – widespread
Mt. Timpoong, 1400 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2573-07.

87. *Octoblepharum albidum* Hedw. – widespread
Mt. Hibok-hibok, 650 m elev., on tree branches; Grassland, May 29, 2007, V.C. Linis 2656-07.

88. **Orthomnion javense* (M.Fleisch.) T.J.Kop. – Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 680 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2438-07. **Mt. Hibok-hibok**, 180 m elev., on tree trunk; Residual Lowland forest, May 29, 2007, V.C. Linis 2631-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2754-07.

89. **O. loheri* Broth. – Luzon
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 800 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2466-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2659-07.

90. **Pelekium investe* (Mitt.) Touw – Luzon and Mindanao
Brgy. Tagdo, Mambajao (footslope of Mt. Hibok-hibok), 180 m elev., on soil near hot spring; Human Settlement area, May 21, 2007, V.C. Linis 2615-07. **Mt. Hibok-hibok**, 850 m elev., on soil; Transitional Lowland forest, May 31, 2007, V.C. Linis 2739-07.

91. **P. synoicum* (Touw) Touw – Luzon and Mindanao
Brgy. Tagdo, Mambajao (footslope of Mt. Hibok-hibok), 200 m elev., on rock near hot spring; Human Settlement area, May 21, 2007, V.C. Linis 2617-07. **Mt. Hibok-hibok**, 850 m elev., on rock; Transitional Lowland forest, May 31, 2007, V.C. Linis 2741-07.

92. *P. velatum* Mitt. – widespread
Mt. Hibok-hibok, 900 m elev., on lower tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2693-07.

93. *Philonotis bartramioides* (Griff.) D. G.Griffin & W.R.Buck – Luzon and Mindanao
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on eroded soil bank; Agricultural land, May 19, 2007, V.C. Linis 2433-07. **Mt. Hibok-hibok**, 180 m elev., on eroded soil bank; Agricultural land, May 29, 2007, V.C. Linis 2626-07. **Mt. Hibok-hibok**, 800 m elev., on eroded soil bank; Secondary Lowland forest, May 31, 2007, V.C. Linis 2749-07.

94. **P. hastata* (Duby) Wijk & Margad. – Luzon and some islands in the Visayas
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on soil; Agricultural land, May 22, 2007, V.C. Linis 2608-07.

95. *P. mollis* (Duby & Molk.) Mitt. – Luzon
Mt. Hibok-hibok, 850 m elev., on soil; Transitional Lowland forest, May 31, 2007, V.C. Linis 2732-07.

96. **Pogonatum camusii* (Thér.) Touw – Luzon and Mindanao
Mt. Timpoong, 1350 m elev., on exposed soil bank near creek; Montane forest, May 21, 2007, V.C. Linis 2621-07.

97. **P. microphyllum* (Dozy & Molk.) Dozy & Molk. – Luzon and some islands in the Visayas
Mt. Hibok-hibok, 850 m elev., on exposed soil bank; Transitional Lowland forest, May 31, 2007, V.C. Linis 2744-07.

98. *P. neesii* (Müll.Hal.) Dozy – widespread
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 680 m elev., on soil bank alongside trail; Lowland forest, May 19, 2007, V.C. Linis 2437-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 720 m elev., on soil bank alongside of trail; Lowland forest, May 19, 2007, V.C. Linis 2454-07. **Mt. Timpoong**, 1350 m elev., on exposed soil bank near creek; Montane forest, May 21, 2007, V.C. Linis 2543-07. **Mt. Hibok-hibok**, 180 m elev., on soil bank alongside trail; Lowland forest, May 29, 2007, V.C. Linis 2630-07. **Mt. Hibok-hibok**, 510 m elev., on soil bank alongside trail; Secondary Lowland forest, May 29, 2007, V.C. Linis 2647-07. **Mt. Hibok-hibok**, 650 m elev., on soil bank alongside trail; Residual Lowland forest, May 31, 2007, V.C. Linis 2753-07. **Mt. Hibok-hibok**, 600 m elev., on soil bank alongside of trail; Residual Lowland forest, May 31, 2007, V.C. Linis 2770-07.

99. *Pseudoleskeopsis zippellii* (Dozy & Molk.) Broth. – Luzon
Mt. Hibok-hibok, 800 m elev., on tree trunk near creek; Transitional Lowland forest, May 31, 2007, V.C. Linis 2745-07.

100. **Pterobryopsis crassicaulis* (Müll.Hal.) M.Fleisch. – Luzon and some islands in the Visayas
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 720 m elev., on lower tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2449-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 850 m elev., on tree branch; Transitional Lowland forest, May 19, 2007, V.C. Linis 2470-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2480-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2489-07. **Mt. Hibok-hibok**, 450 m elev., on lower tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2462-07. **Mt. Hibok-hibok**, 700 m elev., on tree branch; Transitional Lowland forest, May 29, 2007, V.C. Linis 2663-07. **Mt. Hibok-hibok**, 700 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2673-07. **Mt. Hibok-hibok**, 860 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2682-07. **Mt. Hibok-hibok**, 650 m elev., on lower tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2765-07.

101. **P. gedehensis* M.Fleisch. – Luzon and Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 680 m elev., on dead tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2445-07. **Mt. Hibok-hibok**, 320 m elev., on dead tree trunk; Residual Lowland forest, May 29, 2007, V.C. Linis 2638-07. **Mt. Hibok-hibok**, 650 m elev., on dead tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2761-07.

102. *Pyrrhobryum spiniforme* (Hedw.) Mitt. – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on dead tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2503-07. **Mt. Timpoong**, 1530 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2584-07. **Danao, Mambajao** (midslope of Mt.

Timpoong), 1000 m elev., on base of tree trunk; Transitional Lowland forest, May 22, 2007, V.C. Linis 2605-07. **Mt. Hibok-hibok**, 900 m elev., on dead tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2696-07. **Mt. Hibok-hibok**, 850 m elev., on base of tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2729-07.

103. **Racopilum cuspidigerum* (Schwägr.) Ångström – Luzon and some islands in the Visayas
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on base of tree trunk; Agricultural land, May 19, 2007, V.C. Linis 2435-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 740 m elev., on tree root; Lowland forest, May 19, 2007, V.C. Linis 2458-07. **Mt. Hibok-hibok**, 180 m elev., on base of tree trunk; Agricultural land, May 29, 2007, V.C. Linis 2628-07. **Mt. Hibok-hibok**, 600 m elev., on tree root; Residual Lowland forest, May 31, 2007, V.C. Linis 2774-07.

104. *Racopilum spectabile* Reinw. & Hornsch. – widespread
Mt. Hibok-hibok, 800 m elev., on base of tree trunk; Transitional Lowland forest, May 31, 2007, V.C. Linis 2751-07.

105. *Radulina hamata* (Dozy & Molk.) W.R.Buck & B.C.Tan – widespread
Mt. Timpoong, 1250 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2541-07. **Mt. Timpoong**, 1350 m elev., on stem of small tree; Montane forest, May 21, 2007, V.C. Linis 2546-07. **Mt. Timpoong**, 1350 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2549-07. **Mt. Timpoong**, 1350 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2564-07. **Mt. Timpoong**, 1350 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2569-07. **Mt. Timpoong**, 1530 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2587-07.

106. *Sematophyllum microcladioides* (Broth.) Broth. – Luzon and Mindanao
Mt. Hibok-hibok, 700 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2672-07.

107. *Spiridens reinwardtii* Nees – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on trunk of tree ferns; Transitional Lowland forest, May 19, 2007, V.C. Linis 2486-07. **Mt. Timpoong**, 1200 m elev., on trunk of tree fern; Montane forest, May 22, 2007, V.C. Linis 2604-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on trunk of tree ferns; Transitional Lowland forest, May 22, 2007, V.C. Linis 2606-07. **Mt. Hibok-hibok**, 860 m elev., on trunk of tree ferns; Transitional Lowland forest, May 30, 2007, V.C. Linis 2679-07. **Mt. Hibok-hibok**, 1000 m elev., on trunk of tree fern; Montane forest, May 30, 2007, V.C. Linis 2728-07. **Mt. Hibok-hibok**, 850 m elev., on trunk of tree ferns; Transitional Lowland forest, May 31, 2007, V.C. Linis 2730-07.

108. **Symphysodon neckeroides* Dozy & Molk. – Luzon, Mindoro, Palawan and Western Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 720 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2451-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 800 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2467-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 850 m elev., on tree branch; Transitional Lowland forest, May 19, 2007, V.C. Linis 2473-07. **Mt. Hibok-hibok**, 450 m elev., on tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2644-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2660-07. **Mt. Hibok-hibok**, 700 m elev., on tree branch; Transitional Lowland forest, May 29, 2007, V.C. Linis 2666-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2767-07.

109. **Symphysodontella attenuatula* M.Fleisch. – Luzon and Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 720 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2450-07. **Mt. Hibok-hibok**, 450 m elev., on tree trunk; Secondary Lowland forest, May 29, 2007, V.C. Linis 2643-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2766-07.

110. **S. subulata* Broth. – Luzon and Mindoro
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 680 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2440-07. **Brgy. Pandan, Mambajao** (midslope of Mt. Timpoong), 680 m elev., on tree trunk; Lowland forest, May 19, 2007, V.C. Linis 2441-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2501-07. **Mt. Hibok-hibok**, 320 m elev., on tree trunk; Residual Lowland forest, May 29, 2007, V.C. Linis 2633-07. **Mt. Hibok-hibok**, 900 m elev., on tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2694-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk;

Residual Lowland forest, May 31, 2007, V.C. Linis 2756-07. **Mt. Hibok-hibok**, 650 m elev., on tree trunk; Residual Lowland forest, May 31, 2007, V.C. Linis 2757-07.

111. **Syrrhopodon prolifer* Schwägr. – Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1020 m elev., on lower tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2528-07. **Mt. Hibok-hibok**, 1000 m elev., on lower tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2721-07.

112. **S. spiculosus* Hook. & Grev. – Mindoro and some islands in the Visayas
Mt. Timpoong, 1350 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2567-07.

113. *S. tristichus* Nees ex Schwägr. – widespread
Mt. Timpoong, 1350 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2566-07. **Mt. Timpoong**, 1530 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2583-07. **Mt. Timpoong**, 1530 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2588-07. **Mt. Timpoong**, 1530 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2594-07.

114. **Taxithelium alare* Broth. – Luzon and some islands in the Visayas
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on tree branch; Transitional Lowland forest, May 19, 2007, V.C. Linis 2491-07.. **Mt. Hibok-hibok**, 900 m elev., on tree branch; Transitional Lowland forest, May 30, 2007, V.C. Linis 2684-07.

115. *T. instratum* (Brid.) Broth. – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1020 m elev., on dead tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2530-07.

116. **T. nepalense* (Schwägr.) Broth. – Luzon and Mindanao
Brgy. Tagdo, Mambajao (footslope of Mt. Hibok-hibok), 180 m elev., on rock near hot spring; Human Settlement area, May 21, 2007, V.C. Linis 2618-07. **Mt. Hibok-hibok**, 850 m elev., on rock; Transitional Lowland forest, May 31, 2007, V.C. Linis 2742-07.

117. *T. vernieri* (Duby) Besch. – widespread
Mt. Timpoong, 1350 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2561-07. **Mt. Hibok-hibok**, 1000 m elev., on dead tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2723-07.

118. *Thuidium cymbifolium* (Dozy & Molk.) Dozy & Molk. – widespread
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on dead tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2510-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on lower tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2516-07. **Mt. Hibok-hibok**, 900 m elev., on dead tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2703-07. **Mt. Hibok-hibok**, 950 m elev., on lower tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2709-07.

119. **T. plumulosum* (Dozy & Molk.) Dozy & Molk. – Luzon and Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on lower tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2500-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on rocks near creek; Transitional Lowland forest, May 20, 2007, V.C. Linis 2513-07. **Mt. Hibok-hibok**, 950 m elev., on rocks near creek; Transitional Lowland forest, May 30, 2007, V.C. Linis 2706-07.

120. **T. pristocalyx* (Müll.Hal.) A.Jaeger var. *samoanum* (Mitt.) Touw – Luzon and Mindanao
Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 720 m elev., on tree roots; Lowland forest, May 19, 2007, V.C. Linis 2456-07. **Danao, Mambajao** (midslope of Mt. Timpoong), 1000 m elev., on base of tree trunk; Transitional Lowland forest, May 19, 2007, V.C. Linis 2494-07. **Mt. Hibok-hibok**, 510 m elev., on tree roots; Secondary Lowland forest, May 29, 2007, V.C. Linis 2649-07. **Mt. Hibok-hibok**, 900 m elev., on base of tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2687-07. **Mt. Hibok-hibok**, 600 m elev., on tree roots; Residual Lowland forest, May 31, 2007, V.C. Linis 2772-07.

121. **Trachythecium micropyxis* (Broth.) E.B.Bartram – Luzon and Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1020 m elev., on wet rocks; Transitional Lowland forest, May 20, 2007, V.C. Linis 2527-07. **Mt. Hibok-hibok**, 1000 m elev., on wet rocks; Transitional Lowland forest, May 30, 2007, V.C. Linis 2720-07.

122. *T. verrucosum* (A.Jaeger) M.Fleisch. – widespread
Mt. Timpoong, 1350 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2551-07.

123. **Trematodon longicollis* Michx. – Luzon and Mindoro
Sitio Campana, Brgy. Pandan, Mambajao (midslope of Mt. Timpoong), 520 m elev., on soil bank alongside road; Agricultural land, May 19, 2007, V.C. Linis 2429-07.

124. **Trichosteleum stigmosum* Mitt. – Luzon , Mindoro and Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1020 m elev., on dead tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2524-07. **Mt. Hibok-hibok**, 1000 m elev., on dead tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2717-07.

125. **Trismegistia calderensis* (Sull.) Broth. – Luzon and Mindanao
Danao, Mambajao (midslope of Mt. Timpoong), 1000 m elev., on lower tree trunk; Transitional Lowland forest, May 20, 2007, V.C. Linis 2517-07. **Mt. Timpoong**, 1350 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2545-07. **Mt. Timpoong**, 1350 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2555-07. **Mt. Timpoong**, 1350 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2565-07. **Mt. Timpoong**, 1530 m elev., on trunk of dead tree; Montane forest, May 21, 2007, V.C. Linis 2596-07. **Mt. Hibok-hibok**, 950 m elev., on lower tree trunk; Transitional Lowland forest, May 30, 2007, V.C. Linis 2710-07.

126. *T. rigida* (Mitt.) Broth. – widespread
Mt. Timpoong, 1530 m elev., on tree branch; Montane forest, May 21, 2007, V.C. Linis 2575-07. **Mt. Timpoong**, 1530 m elev., on tree trunk; Montane forest, May 21, 2007, V.C. Linis 2590-07.

127. *Vesicularia montagnei* (Schimp.) Broth. – widespread
Brgy. Tagdo, Mambajao (footslope of Mt. Hibok-hibok), 180 m elev., on wet soil and rocks near hot spring; Human Settlement area, May 21, 2007, V.C. Linis 2619-07.

128. *V. reticulata* (Dozy & Molk.) Broth. – widespread
Mt. Hibok-hibok, 600 m elev., on moist soil and rocks beside trail; Transitional Lowland forest, May 31, 2007, V.C. Linis 2776-07.

129. **Warburgiella breviseta* (Broth.) Broth. – Luzon and Mindanao
Mt. Timpoong, 1350 m elev., on dead tree trunk; Montane forest, May 21, 2007, V.C. Linis 2562-07.

Corrigenda —Telopea 12 (3)

Restionoideae Arn. not Restionoideae Link

Briggs BG & Linder HP (2009) A new subfamilial and tribal classification of Restionaceae (Poales). Telopea 12: 333–345.

We wish to correct errors in this paper.

Reference was made to Haplatherae and Diplantherae, designations within Restionaceae by Bentham and Hooker (1883) but we overlooked a relevant aspect, that names of infrafamilial taxa not based on a generic name are not valid and cannot be typified. It was therefore inappropriate to propose a lectotype for Haplatherae.

Also, the long-accepted citation Restionoideae Link, *Handbuch* 1: 134 (1829), that we adopted is incorrect. The International Code of Botanical Nomenclature [McNeill et al. 2006]; Reveal 1995) specifically states (Article 35.5 Ex. 6):

> In Link's *Handbuch* (1829-1833) the rank-denoting term "O." (ordo) was used in all three volumes. These names of orders cannot be considered as having been published as names of families (Art. 18.2) since the term family was used for *Agaricaceae* and *Tremellaceae* under the order *Fungi* in vol. 3 (pp. 272, 337; see Art. 18 Note 1). This applies to all three volumes of the *Handbuch*, even though vol. 3 was published later (Jul - 29 Sep 1833) than vols. 1 and 2 (4-11 Jul 1829).

Thus Restionineae Link (1829) is to be treated as a suborder, rather than a subfamily. Restionoideae Arn. (as Restieae) was validated by a description in English (Arnott 1832). Therefore, on page 340 of our paper, the heading 'Restionoideae Bartl.' should also be corrected to 'Restionoideae Arn.'

We are most grateful to James Reveal for clarifying these matters for us. We also thank Gillian Perry and Peter Wilson for helpful comments. David Mabberley and James Wearn kindly provided images from Arnott's publication in the KEW Library.

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